APPENDIX B

Engineering Analysis

Final Engineering Analysis
Shoreline Protection Project
Town of North Topsail Beach, North Carolina

Prepared for:

North Topsail Beach, North Carolina

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Executive Summary

North Topsail Beach has an 11.1 mile ocean shoreline that occupies the north end of Topsail Island. The Town is bordered on the south by the Town of Surf City and on the north by New River Inlet. Development and infrastructure within the corporate limits of the North Topsail Beach have been damaged during recent storm events and remain vulnerable to damage associated with coastal storms. The north end of the Town is the most vulnerable area due to erosion and shoreline fluctuations caused by uncontrolled changes in position and alignment of the New River Inlet ocean bar channel. The Town is seeking Federal and State permits to allow implementation of a non-Federally funded shoreline and inlet management project that would preserve the Town's tax base, protect its infrastructure, and maintain its tourist oriented economy.

Most of the northern 7.25 miles of the town's shoreline (shoreline north of baseline station 785+00) lies within the Coastal Barrier Resource System (CBRS) and is not eligible for federal storm damage protection. The southern 3.85 miles is presently being evaluated for a possible federal storm damage reduction project.

Seven alternatives were considered and the applicant's preferred alternative is Alternative 3: Implementation of an Inlet Management Plan for New River Inlet and construction of a beach fill along 11.1 miles of the Town's shoreline. The design template for the beach fill within the CBRS includes an artificial dune with a crest elevation of +14.0 feet above NAVD fronted by a variable width horizontal beach berm at elevation +6.0 feet NAVD. The dune feature of the template would only be constructed in areas where the existing dune is inadequate. The beach fill proposed for the southern 3.85 miles is only intended to provide interim projection until such time the federal storm damage reduction project is implemented. The design template for the beach fill along the southern 3.85 miles consists of a horizontal berm at elevation +6.0 feet NAVD.

The inlet management plan includes repositioning the of the main ocean bar channel to a more southerly alignment and periodic maintenance of the preferred position and alignment. The new channel would be constructed to a bottom width of 500 feet and a depth of -18 feet NAVD. Construction of the new channel would require the removal of 635,800 cubic yards of material based on the most recent survey of New River Inlet. Of this total volume 544,400 cubic yards is compatible with the native beach and 91,400 cubic yards incompatible. The incompatible material, which would be deposited in an upland disposal area, consists of a mixture of clay and shells. The compatible inlet material has an average mean grain size of 0.39 mm and would be used to initially construct the beach fill portion of the project along the northern 1.7 miles (9,000 feet) of the project area.

Maintenance of the new channel in the preferred position and along the preferred alignment is critical for the recovery of the extreme northern end of the town's shoreline. Therefore, the inlet management plan includes two channel thresholds which could trigger channel maintenance. The first threshold is based on shoaling of the new channel while the second is based on the position and orientation of the channel. For the shoaling threshold, channel maintenance would

be required when shoaling of the new channel reaches 85% of the initial dredge volume. The position threshold would be exceeded when the channel migrates outside the preferred channel corridor established during initial construction. The time required for the channel to migrate out of the preferred corridor is not known, however; channel shoaling is expected to reach the 85% threshold within 3 to 4 years after construction. Accordingly, formulation of the inlet management plan portion of the project assumed channel maintenance would be required at least every 4 years.

An offshore borrow area has been identified to provide beach fill for the remaining 9.4 miles of the North Topsail Beach shoreline. The borrow area is horseshoe shaped and located between 1 and 2 miles offshore, due south of the Town Hall. The borrow area contains approximately 6,551,000 cubic yards, 357,000 cubic yards of which is coarse material with a mean grain size of 0.33 mm and the balance composed of finer material with a mean grain size of 0.21 mm. The native beach has a mean grain size of 0.23mm.

Hardbottoms exist offshore of North Topsail Beach with some hardbottom areas located approximately 900 to 3,600 ft from the baseline stations. In order to avoid direct impacts on these relatively close hardbottom areas, coarse fill material from the offshore borrow area or from the construction and/or maintenance of the new channel in New River Inlet will be placed in these areas. The use of coarser fill material will require less volume to construct the design beach fill template and will move the point of intercept of the fill with the existing beach profile well landward of the nearshore hardbottom areas. The point of intercept is the seaward most point where the beach fill would ultimately tie into the existing bottom following post-construction adjustments.

The Town of North Topsail Beach proposes to construct the project in 5 phases based on its anticipated funding stream. The first phase of construction would occur between 16 November 2010 and 31 March 2011 (environmental dredging window) and would involve the relocation of the New River Inlet channel. Material from the channel relocation would be used to construct 9,000 feet of the beach fill from baseline station 1160+00, located next to New River Inlet, to 1070+00. Phase II would occur during the November 2012 to March 2013 dredging window and would cover 10,120 feet of shoreline between baseline stations 968+80 to 1070+00. Material for Phase II would come from the offshore borrow area. Coarse material from the offshore borrow area would be placed between baseline stations 1020+00 and 1070+00 (nearshore hardbottom areas) with the balance of the area constructed with material from the northeast portion of the borrow area.

Phase III would be scheduled for the November 2014 to March 2015 dredging window or 4 years after the initial channel relocation and would cover the shoreline between baseline stations 785+00 and 900+00. This is an area that includes hardbottoms approximately 900 to 2,700 ft from the baseline stations and would be constructed using coarse material from either the offshore borrow area or coarse shoal material removed to reestablish the position and alignment of the inlet bar channel. Based on shoaling predictions in the new channel, the 85% shoaling threshold would be exceeded within the first four years following channel relocation which would trigger the first channel maintenance operation. The predicted shoaling of the new channel would be sufficient to initially construct the beach fill in Phase III and provide periodic nourishment for the beach fill constructed during Phase I.

Phase IV, which would be scheduled for the 2016 to 2017 environmental dredging window, would be constructed using material from the offshore borrow area and would cover the shoreline north of station 900+00 to 968+80. Phase IV would complete the beach fill within the North and Central Sections of North Topsail Beach. Construction of Phase IV would also correspond to the time nourishment could be required along the Phase II shoreline (968+80 to 1070+00). Since channel maintenance would not be scheduled at this time, nourishment of Phase II would be accomplished using coarse material from the offshore borrow area.

Phase V, the final initial construction phase, would occur during the 2018 to 2019 environmental dredging window and would provide an interim beach fill along the southern 20,320 feet of the town's shoreline. Phase V would also be constructed using material from the offshore borrow area.

Construction of Phase V would be scheduled 8 years after initial construction of the new bar channel in New River Inlet and, based on the theoretical shoaling predictions, could occur at the same time maintenance of the new channel is required. By this time, all or portions of the shoreline segments constructed during Phases I to IV would be in need of periodic nourishment, therefore, the inlet channel maintenance material could be deposited between the inlet and baseline station 785+00. The exact location of disposal would depend on the performance of the fill placed in the four segments.

Following initial construction of the beach fill portion of the project, material removed to maintain the preferred channel position and alignment would be used to provide periodic nourishment of the beach fill between station 785+00 and New River Inlet.

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INTRODUCTION

Project Area

North Topsail Beach has an 11.1 mile ocean shoreline that occupies the north end of Topsail Island. The Town is bordered on the south by the Town of Surf City (baseline station 581+80) and on the north by New River Inlet (Figure 1). Onslow Beach, which is located on the north side of New River Inlet, is part of the Marine Corps Base - Camp Lejeune. North Topsail Beach is accessible from the mainland by NC Highway 210 that intersects with NC 172 and US Highway 17 northwest of the Town. NC 210 crosses the Atlantic Intracoastal Waterway (AIWW) via a high rise bridge and enters the Town near Town Hall.

Project Purposes

The Town of North Topsail Beach is seeking Federal and State permits to allow implementation of a non-Federal shoreline and inlet management project that would preserve the Town's tax base, protect its infrastructure, and maintain its tourist oriented economy. The total assessed tax value of property within the corporate limits of North Topsail Beach is approximately $1.49 billion based on the 2006 reappraisal. Of this total tax base, $0.79 billion is situated within a 150- to 400-foot wide strip of land generally located between the frontal dune and the ocean front roads. NC 210 is the ocean front road south of Town Hall while New River Inlet Road extends from Town Hall to New River Inlet (Figure 1).

PROBLEM IDENTIFICATION

Coastal Hazards and Concerns

North Topsail Beach has low relief with elevations in the areas located landward of the frontal dune ranging from 5 to 9 feet above North American Vertical Datum (NAVD). The frontal dune is relatively thin and has been reconstructed on several occasions following coastal storms, most recently following Hurricane Ophelia, which impacted the area in September 2005. Even with the dune reconstruction, development and infrastructure within the corporate limits of the North Topsail Beach remain vulnerable to damage associated with coastal storms, including tropical cyclones and nor'easters. Long-term shoreline erosion and shoreline fluctuations at its north end, associated with uncontrolled changes in the position and alignment of the ocean bar channel of New River Inlet, also increase the Town's vulnerability.

The instability of the shoreline immediately southwest of New River Inlet poses the most immediate shoreline management concern. During the past year, 17 duplex structures located at the extreme north end of Town, which have a total tax value of over $17 million, have become

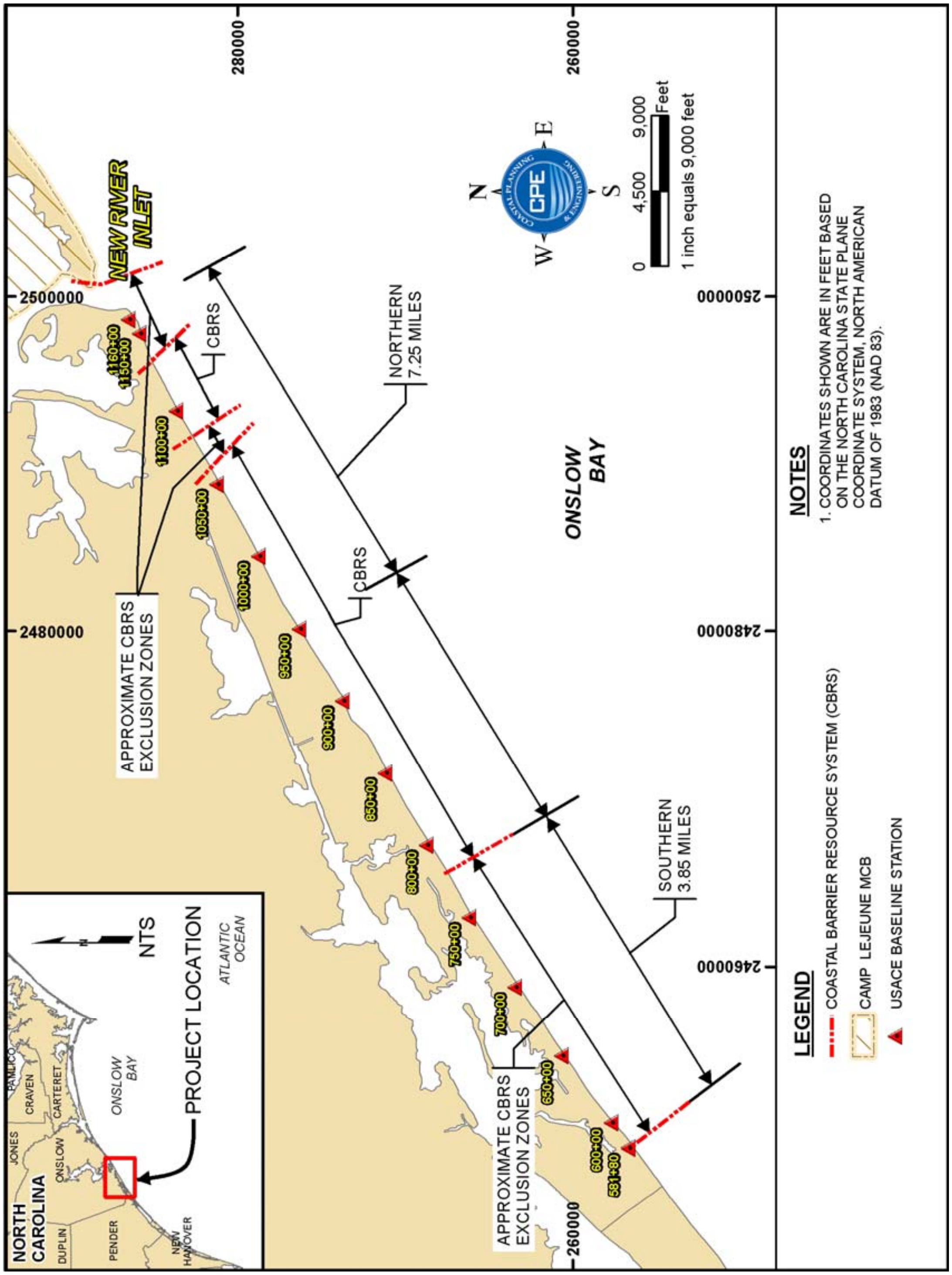


Figure 1. Town of North Topsail Beach with baseline stations, and approximate CBRS boundaries.

imminently threatened. Attempts have been made by individual property owners to protect the threatened duplexes with sandbag revetments; however, most of the sandbag revetments have failed to provide any substantial degree of protection. Two of the imminently threatened duplexes were relocated to other parts of North Topsail Beach at the expense of the property owners. Some of the remaining duplexes have been declared uninhabitable due to the loss of water, sewer, and electrical connections and could eventually be ordered to be removed or demolished.

Impact of Recent Hurricanes

The Town of North Topsail Beach was severely impacted by Hurricanes Bertha and Fran in 1996 and to a lesser extent by Hurricane Bonnie in 1998, and Hurricanes Dennis, Floyd, and Irene in 1999. Hurricane Bertha made landfall near Cape Fear on 12 July 1996 as a Category 2 hurricane. Maximum sustained winds at the time Bertha made landfall were approximately 105 mph. Structural damage on Topsail Island and North Topsail Beach due to Hurricane Bertha was relatively light; however, Bertha severely eroded the frontal dune and overwashed the island in numerous places. Bertha was followed 6 weeks later by Hurricane Fran, which also made landfall near Cape Fear during the evening and morning hours of 5-6 September 1996. Hurricane Fran was a Category 3 hurricane at the time of landfall with sustained winds of between 115 and 120 mph and produced still water levels in the area ranging from 8 to 11 feet above NAVD.

North Topsail Beach suffered considerable damage as a result of the severely weakened dune system associated with Hurricane Bertha and the high storm tides that accompanied Fran. Several hundred homes (including a large number of mobile homes) were completely destroyed or damaged beyond repair while the Town's power, water, and sewer systems required extensive repairs. Based on interviews with local officials, the Corps of Engineers (USACE, 2000) estimated the total damages along North Topsail Beach at $72 million. The only area of North Topsail Beach that was not significantly impacted by Hurricane Fran was the northernmost one-mile segment located immediately southwest of New River Inlet. Due to its proximity to the inlet, this particular area had a wide beach and more significant dune system that protected the buildings from the direct impacts of the hurricane storm surge and waves.

A photo of the north end of North Topsail Beach taken in November 1995 by Dr. Bill Cleary of the University of North Carolina at Wilmington (UNCW) is shown in Figure 2. A group of townhouses and an old roadbed are identified on this photo along with two land bridges, one located near baseline station 1040+00 and the other near station 1060+00. The land bridges were constructed to avoid impacts to wetlands when New River Inlet Road was relocated toward the sound. Also note the seaward bulge in the shoreline near New River Inlet. As discussed later in this report, the seaward bulge or curvature in the shoreline is due to New River Inlet and the associated wave refraction and sediment transport patterns influenced by the inlet's ebb tide delta.

Figure 2. North Topsail Beach, November 1995 (Photo courtesy of Dr. Bill Cleary, UNCW).

A photo of the same general area taken by Dr. Cleary on 6 September 1996, the day after Hurricane Fran, is shown in Figure 3. North Topsail Beach was inundated by the combination of storm surge and wave action, which breached the island in several locations, causing extensive damage to New River Inlet Road and underground utilities. Two of the breaches, shown in Figure 3, coincided with the location of the land bridges identified in Figure 2. Most of the breaches closed within a few days to a few weeks; however, the northernmost breach located in the vicinity of station 1060+00 remained open for almost a year before closing naturally. The damage to New River Inlet Road and utilities isolated the north portion of North Topsail Beach for several months.

Figure 3. North Topsail Beach, September 1996 after Hurricane Fran (Photo courtesy Dr. Bill Cleary, UNCW).

Hurricane Fran stripped large quantities of sand from the beach exposing old lagoonal peat along the foreshore (Figure 3). A considerable quantity of sand was carried into and deposited in the sound as overwash fans. The post-storm topography of over 90% of North Topsail Beach consisted of a relatively flat foreshore with no dune system as demonstrated in Figure 4.

Hurricane Ophelia impacted North Topsail Beach during the first week of September 2005 and caused significant erosion of the dune system. An example of the dune erosion associated with Hurricane Ophelia is shown in Figure 5, which was taken on September 6, 2005 in front of the Hampton Colony development (baseline station 870+00). Between January and April 2006, the Town of North Topsail Beach, with funding assistance provided by the Federal Emergency Management Agency (FEMA), rebuilt the dune system. The dune repairs, which cost an estimated $2.0 million ($1.5 million from FEMA and $500,000 from the Town of North Topsail Beach) was accomplished through a combination of truck haul material from an inland borrow pit and scraping sand from the immediate foreshore.

Figure 4. Post-Hurricane Fran photo by Corps of Engineers of North Topsail Beach in the vicinity of 23rd and 24th Avenues (between baseline stations 680+00 and 690+00).

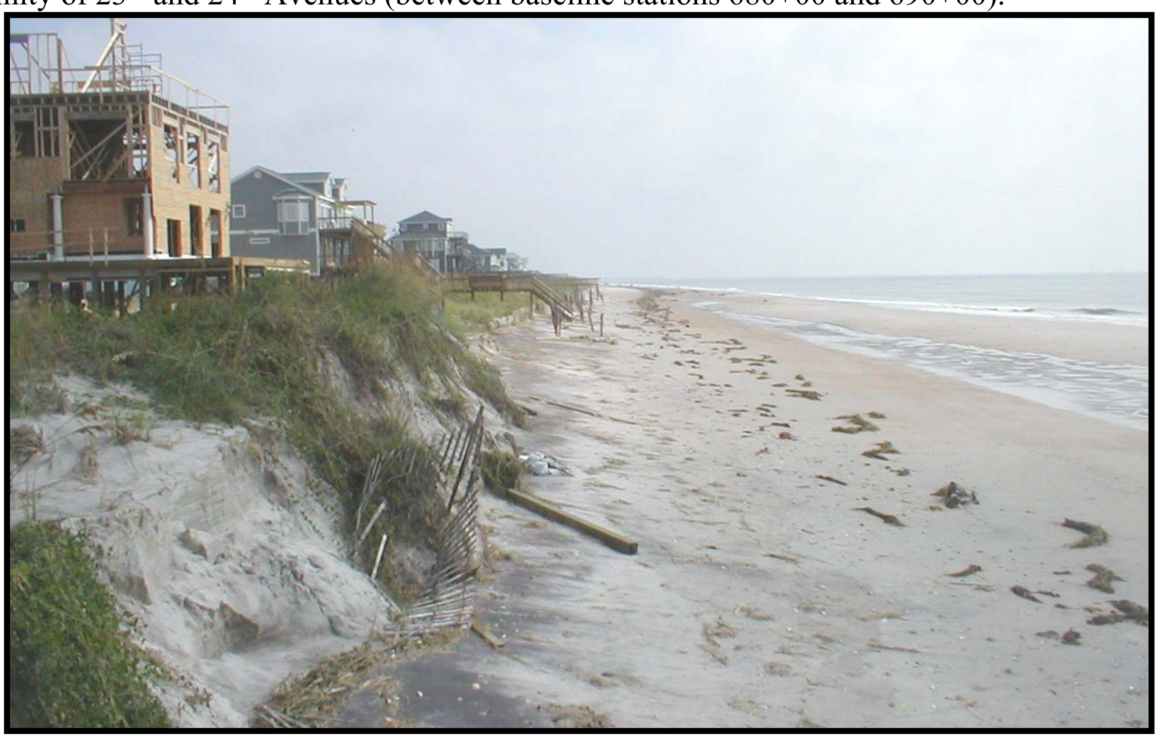


Figure 5. Post Hurricane Ophelia photo (9/6/05) in vicinity of station 870+00 (Hampton Colony) showing erosion of dune.

COASTAL BARRIER RESOURCE SYSTEM (CBRS)

Description of CBRS on North Topsail Beach

Most of the northern 7.25 miles of the Town (Figure 1) lies within the Coastal Barrier Resource System (CBRS), which was established pursuant to the Coastal Barrier Resource Act of 1982 (CBRA-82) and the Coastal Barrier Improvement Act of 1990 (CBIA-90). The purpose of these two acts is to restrict Federal expenditures and financial assistance on undeveloped coastal barrier islands that would encourage development. The U.S. Fish and Wildlife Service (USFWS) is the Federal agency responsible for administering the CBRS. The USFWS drew the CBRS boundaries following the passage of CBRA-82 and included all undeveloped areas on the barrier islands that existed at that time. As a result, all except two relatively small areas along the northern end of North Topsail Beach were included in the CBRS. The southern 3.85 miles of the Town were also excluded from the CBRS, as this area was already developed. The approximate locations of the CBRS boundaries on North Topsail Beach are shown in Figure 1. The two areas in the northern 7.25-mile segment excluded from the CBRS include a 1,950-foot segment beginning approximately 1,500 feet southwest of New River Inlet and a 1,900-foot segment that begins approximately 8,600 feet southwest of the inlet.

Impact of CBRS on Federal Storm Damage Protection

The U.S. Army Corps of Engineers (USACE) initiated a federal coastal storm damage reduction study for the Towns of North Topsail Beach and Surf City in February 2002. Based on restrictions imposed within the CBRS, the Corps determined that the northern 7.25 miles of the Town's shoreline, including the two CBRS exclusion zones, would not be eligible for Federal protection. With regard to the two CBRS exclusion zones, USACE concluded that the zones are too short to accommodate an economical shoreline protection solution without impacting the adjacent CBRS.

The southern 3.85 miles of the Town's shoreline (Figure 1) is eligible for consideration for Federal protection and is included in the Corps of Engineers feasibility study. At the present time (November 2006), the Corps of Engineers is in the plan formulation stage for the federal storm damage reduction project. When completed, the study recommendations will go to Congress for authorization. Assuming that the federal feasibility study will determine protection of the southern portion of North Topsail Beach is in the federal interest, advanced engineering and design would be initiated followed by right-of-way acquisitions and construction. Based on the present status, construction of a federal storm damage reduction project along the southern 3.85 miles of North Topsail Beach will probably not begin until at least 2012 or possibly later.

NON-FEDERAL SHORELINE PROTECTION PROJECT

Northern 7.25 Miles

The Town of North Topsail Beach initiated efforts to develop a non-Federal shoreline protection project for the northern 7.25 miles of its shoreline in February 2003 by contracting with Coastal Planning & Engineering of NC, Inc. (CPE-NC) to conduct a feasibility study. CPE-NC was assisted in the feasibility study by its parent company, Coastal Planning & Engineering, Inc. (CPE) of Boca Raton, Florida. The final feasibility study was provided to the Town of North Topsail Beach in August 2004 (CPE-NC, 2004). The feasibility report recommended a multi-faceted approach that included an inlet management plan for New River Inlet and beach fill along the 7.25 mile shoreline. In September 2004, the Town contracted with CPE-NC to develop final designs for the project and obtain Federal and State permits and other clearances required for project implementation.

Southern 3.85 Miles

With the prospect that federal protection for the southern 3.85 miles of the Town's shoreline may not be implemented until 2012 or later, the North Topsail Beach Board of Aldermen voted on May 4, 2006 to include an interim or emergency beach fill project in its non-Federal effort. The CPE-NC contract was amended to include the development of an emergency beach fill project that would be designed to maintain shoreline conditions comparable to those used by the Corps of Engineers in formulating the economic feasibility for a federal storm damage reduction project. In this regard, the Corps of Engineers economic analysis was based on shoreline conditions that existed in 2002.

Alternatives

A Project Delivery Team (PDT) for the North Topsail Beach Project was established to guide the formulation of the non-Federal project, identify environmental issues and concerns, develop pre- and post-construction environmental monitoring plans, and formulate alternatives that would address all or most of the project purposes. The PDT, which was headed by the Wilmington District Corps of Engineers Regulatory Office, included representatives from the following Federal and State agencies and other interest groups:

USACE – Regulatory Office
USACE – Navigation Branch
U.S. Fish & Wildlife Service
National Marine Fisheries Service
US Marine Corps
U.S. Environmental Protection Agency
NC Division of Coastal Management (State Regulatory Agency)
NC Division of Water Quality
NC Division of Marine Fisheries
NC Wildlife Resources Commission

Environmental Defense Fund
NC Beach Inlet and Waterway Association
NC Coastal Federation
Onslow County
Town of North Topsail Beach

The PDT developed the following seven (7) alternatives for consideration:

Alternative 1 – No Action Alternative. The Town of North Topsail Beach and its property owners would continue to respond to erosion and storm related problems as they have in the past including the use of temporary sandbag revetments.

Alternative 2 – Buy-Out Alternative. The Buy-Out Alternative is similar to the No Action Alternative except temporary sandbag revetments would not be used to protect individual properties. Sandbags would be used to protect threatened sections of New River Inlet Road.

Alternative 3 – Applicant's Preferred Alternative. This alternative includes implementation of an inlet management plan for New River Inlet, construction of a beach fill project along the northern 7.25 miles of the Town's shoreline, and construction of an emergency beach fill along the southern 3.85 miles of shoreline. The inlet management plan includes the initial repositioning of the main ocean bar channel to a preferred alignment and periodic maintenance of the preferred alignment. Material from the maintenance of the channel would be used to provide periodic nourishment of the northern 7.25 mile beach fill.

Alternative 4 – Beach Nourishment without the Inlet Management Plan. The beach fill along the northern 7.25 miles of the Town's shoreline and the emergency beach fill for the southern 3.85 miles would be constructed using material from an offshore borrow area and/or upland borrow sites.

Alternative 5 – Beach Nourishment with One-Time Relocation of New River Inlet Bar Channel. The beach fill along the northern 7.25 miles and southern 3.85 miles would be the same as Alternative 3. The New River Inlet bar channel would only be relocated one time. Periodic nourishment material for the northern 7.25 miles of the beach fill would be derived from the offshore borrow areas or from upland borrow sites.

Alternative 6 – Inlet Management Plan. The New River Inlet ocean bar channel would be realigned and maintained along its preferred alignment. Material removed to construct and maintain the preferred channel would be evenly distributed along the northern 7.25 miles of the Town's shoreline. The emergency beach fill project for the South Section would be constructed using the offshore borrow area.

Alternative 7 – Terminal Groin. A terminal groin would be constructed on the south shoulder of New River Inlet to protect the extreme northeast end of the Town's shoreline from the impacts of New River Inlet. Since the State of North Carolina has adopted legislation prohibiting the use of this type of structure, the terminal groin alternative was not critically evaluated in the engineering analysis.

Report Organization

Pertinent information applicable to the evaluation of all of the alternatives listed above is provided in the following sections. The pertinent information includes:

(a) horizontal and vertical controls;
(b) sand transport rates;
(c) historic ocean shoreline changes;
(d) beach profiles;
(e) location of nearshore hardbottom resources;
(f) native beach material characteristics; and
(g) geotechnical investigations,

Subsequent sections of the report provide the formulation of the inlet management plan and development of the beach fill options. The most pressing shoreline management issue facing the Town of North Topsail Beach is associated with the impacts of New River Inlet on the extreme northeast end of the Town's shoreline. Development of an effective inlet management plan is also an essential element of several of the alternatives listed above, including the Applicant's Preferred Alternative (Alternative 3). Accordingly, a plan for managing New River Inlet will be presented first, followed by an evaluation of beach nourishment options for the northern 7.25 miles of the Town's shoreline and development of the emergency beach fill plan for the southern 3.85 miles.

The various project elements (inlet management, beach fill design for the northern 7.25 miles, and design of the emergency beach fill for the southern 3.85 miles) will be incorporated into the alternative listed above and each alternative evaluated for its ability to satisfy the primary project purpose; preservation of the Town's tax base and infrastructure.

HORIZONTAL AND VERTICAL CONTROLS

Horizontal Control

The Corps of Engineers has established a baseline along the entire length of Topsail Island that is referenced to the North American Datum of 1983 (NAD '83). The baseline on North Topsail Beach begins at station 581+80 located on the boundary between North Topsail Beach and the Town of Surf City and ends at station 1168+00 on the south shoulder of New River Inlet (Figure 1). The CBRS boundary separating the northern 7.25 miles and the southern 3.85 miles of the Town's shoreline is located at approximately station 785+00.

The Corps divided the shoreline of Topsail Island into 1000-foot reaches to facilitate its economic analysis. The 1000-foot reaches are centered on each 1000-foot baseline station. For example, Reach 60 is centered on Corps baseline station 600+00, Reach 100 is centered on Corps baseline station 1000+00, etc. The 1,000-foot shoreline reaches established by the Corps were also used in economic evaluations conducted for this report.

Vertical Control

Elevations in this report are referenced to the North American Vertical Datum of 1988 (NAVD '88). The approximate relation between NAVD '88 and other vertical datums at NOAA Tidal benchmark 8658559 (Wilmington Beach Pier) for the project area are as follows:

Mean Higher High Water …………………………	1.74 feet
Mean High Water …………………………………	1.40 feet
NAVD '88 …………………………………………	0.00 feet
Mean Sea Level……………………………………	-0.70 feet
NGVD '29 …………………………………………	-0.95 feet
Mean Low Water …………………………………	-2.81 feet
Mean Lower Low Water …………………………	-2.96 feet

The North Carolina Coastal Resources Commission, the State agency that establishes coastal regulations and standards, adopted new rules regarding sediment compatibility for beach nourishment projects that went into effect on February 1, 2007. The sediment standards adopted NAVD '88 as the vertical datum. Accordingly, the EIS for the North Topsail Beach project will refer to elevations relative to NAVD '88. As noted above, NAVD '88 is approximately 1.0 foot above the NGVD '29 datum.

LITTORAL SAND TRANSPORT RATES

Wave Information

Longshore sediment transport rates for North Topsail Beach were computed based on WIS (Wave Information Study) wave hindcast information developed by the U.S. Army Corps of Engineers Coastal Hydraulics Laboratory located in Vicksburg, Mississippi (USACE, 1995). The WIS data used for this analysis was obtained from WIS Phase II Station AU2044 located at 34.25° north latitude and 77.25° west longitude or directly offshore of New River Inlet a water depth of 12 fathoms (72 feet) as shown on Figure 6. The WIS wave information is given for every three hours throughout the 20-year hindcast period (1976 to 1995).

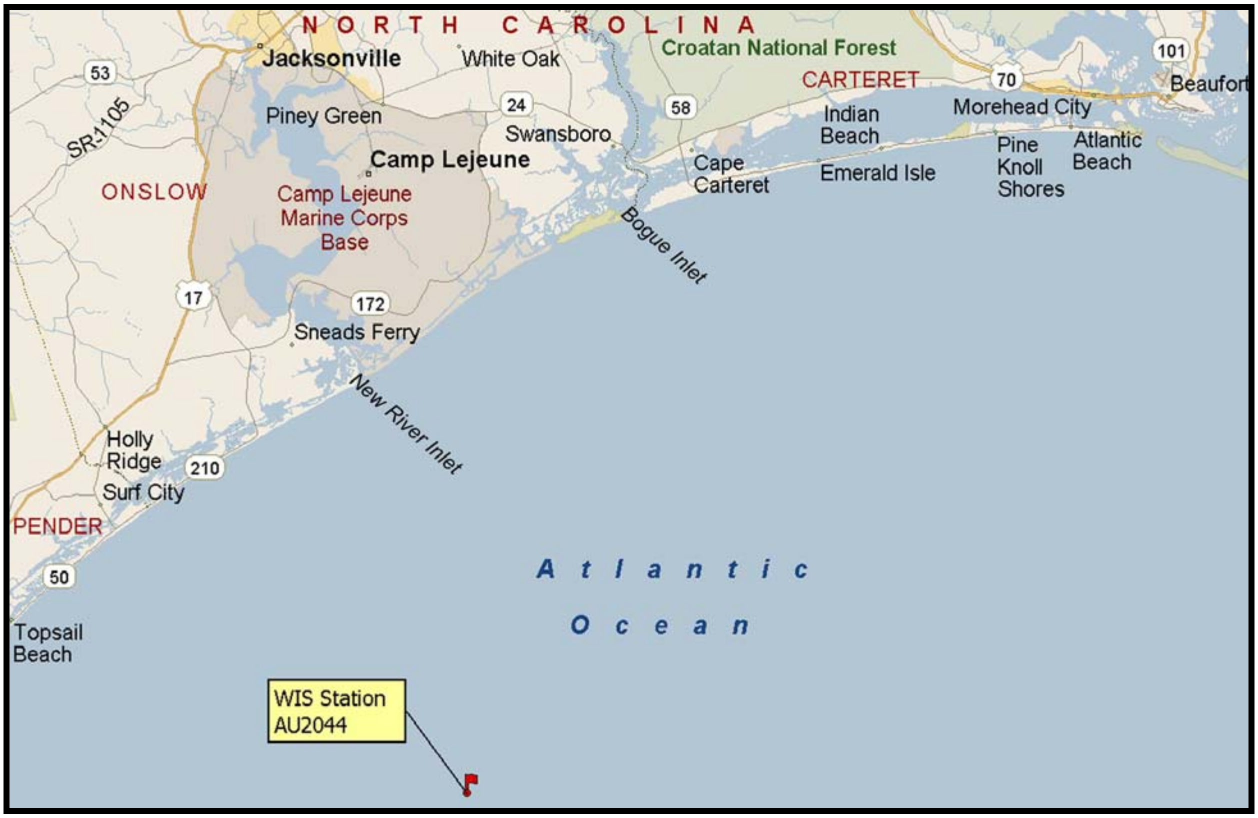


Figure 6. Location of WIS Station AU2044.

Potential Sand Transport Rates

The wave information at the reporting site (AU2044) for each 3-hour hindcast was transformed toward the beach to a point near breaking using linear wave theory. The transformed wave conditions were used to compute the potential for longshore sediment transport for each 3-hour hindcast using the following equation (USACE, 1984):

$$Q = 7500(.00996)\rho g^2 T(H_{so})^2 (\sin \alpha_2) (\cos \alpha_1) (3 \text{ hrs./t})$$

Where: Q = Potential longshore sediment transport rate (cy/yr)
ρ = mass density of seawater (1.99 slugs/ft^3)
g = acceleration due to gravity (32.2 ft/sec^2)
T = wave period in seconds for the 3-hr hindcast
H_{so} = deepwater significant wave height for the 3-hr hindcast
α_1 = angle between wave crest and shoreline in deep water
α_2 = angel between wave crest and shoreline near break point
t = number of hours in a year

A summary of the potential longshore sediment transport for each year between 1976 and 1995 is given in Table 1. Note that the sediment transport rates given in this table were computed for a shoreline orientation of N 60^o E which is the approximate shoreline orientation southwest of

New River Inlet. Average monthly transport rates are given in Table 2 with a plot of the monthly northeast and southwest transport rates given in Figure 7. As noted in Figure 8, the months that exhibited relatively high potential sediment transport rates correlated well with hurricane events and known nor'easters thus providing confidence in the WIS wave information. In general, longshore transport in the study area is predominantly to the southwest; however, reversals in longshore transport predominance, i.e., predominant transport to the northeast, may occur during the months of March through July. Also, two years in the 20-year hindcast record, 1988 and 1994, actually had predominate transport to the northeast.

Table 1. Summary of computed longshore transport by year, WIS Station AU2044, shore orientation N 60^{o} E.

Year	Northeast	Southwest	Gross	Net[(a)]
1976	-348,700	438,600	787,200	89,900
1977	-277,900	430,800	708,700	152,800
1978	-357,300	469,600	826,900	112,200
1979	-405,100	608,200	1,013,300	203,100
1980	-275,800	817,900	1,093,600	542,100
1981	-317,700	559,900	877,600	242,100
1982	-184,300	444,000	628,400	259,700
1983	-280,300	591,500	871,800	311,100
1984	-309,700	625,700	935,400	316,000
1985	-237,700	538,000	775,600	300,300
1986	-226,000	547,800	773,800	321,900
1987	-172,100	559,100	731,200	387,000
1988	-320,900	298,000	618,900	-22,900
1989	-346,500	649,800	996,300	303,300
1990	-385,500	534,100	919,600	148,600
1991	-306,800	500,400	807,100	193,600
1992	-194,400	451,700	646,000	257,300
1993	-254,300	612,100	866,400	357,800
1994	-444,000	431,700	875,600	-12,300
1995	-288,700	328,100	616,800	39,400
Average	**-296,700**	**521,900**	**818,500**	**225,200**

[(a)] + = Net Transport to the Southwest, - = Net Transport to the Northeast.

Table 2. Average monthly transport rates (cy/yr), WIS Station AU2044, 1976 to 1995, shore orientation N 60° E.

Month	Northeast	Southwest	Gross	Net[(a)]
Jan	-30,600	53,600	84,200	23,000
Feb	-30,300	44,900	75,200	14,600
Mar	-55,500	47,000	102,500	-8,500
Apr	-38,000	34,400	72,400	-3,600
May	-27,000	28,100	55,100	1,100
Jun	-21,100	19,200	40,300	-1,900
Jul	-21,900	14,100	36,000	-7,800
Aug	-10,600	31,100	41,700	20,500
Sep	-8,800	78,500	87,300	69,700
Oct	-6,600	57,600	64,200	51,000
Nov	-19,500	60,000	79,500	40,500
Dec	-26,700	53,300	80,000	26,600
Total	**-296,700**	**521,900**	**818,500**	**225,200**

(a) + = Net Transport to the Southwest, - = Net Transport to the Northeast.

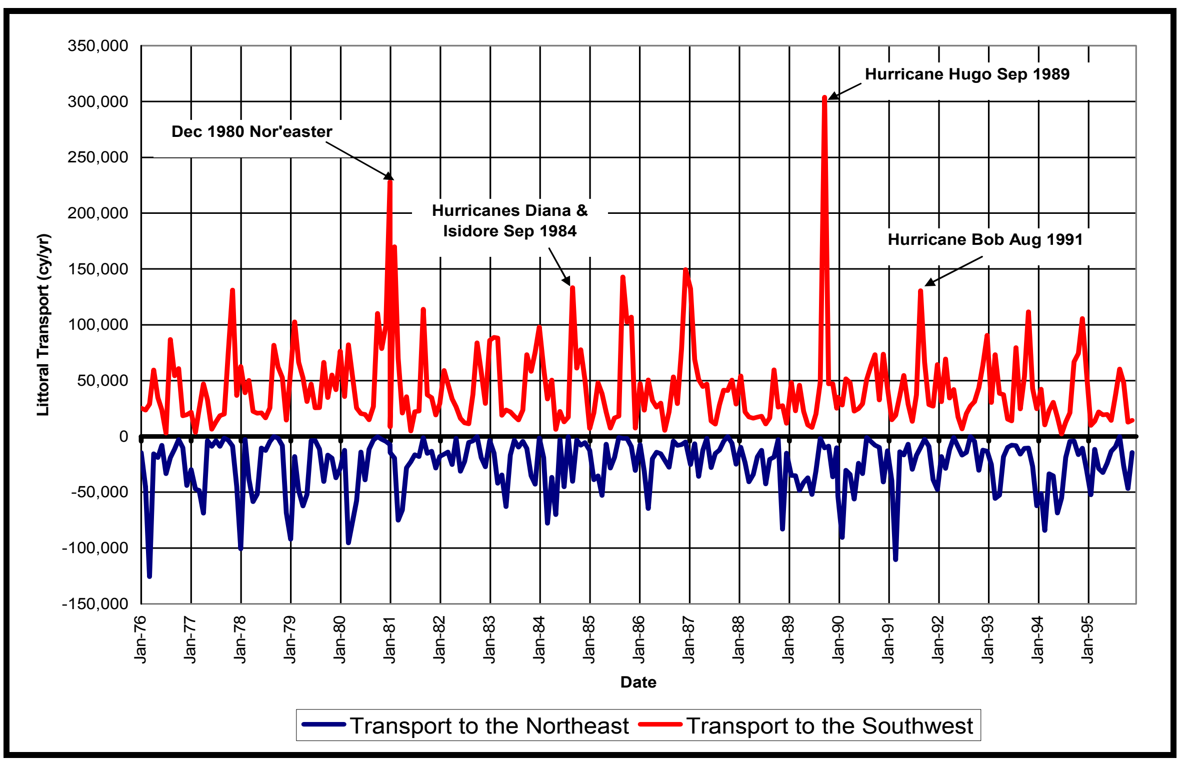


Figure 7. Monthly sediment transport, 1976 to 1995, (WIS Station AU2044).

Sediment transport rates were also determined for other shoreline orientations applicable to the study area. The relationships between shoreline orientation and northeast and southwest transport rates are shown in Figure 8. These relationships will be used later in this document to develop a sediment budget in the vicinity of New River Inlet.

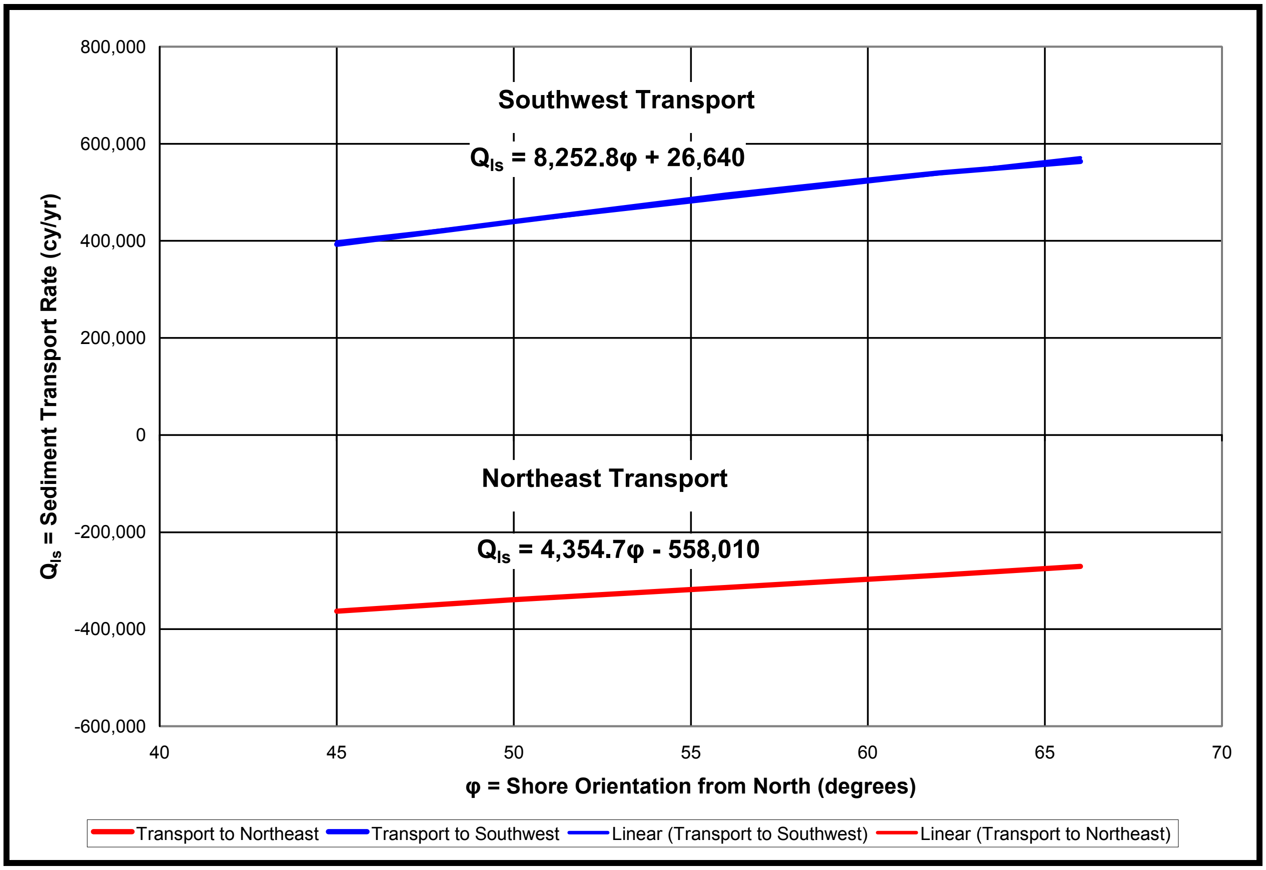


Figure 8. Sediment transport versus shore orientation.

OCEAN SHORELINE CHANGES

Shoreline Change Data

Shoreline change rates for North Topsail Beach developed by the North Carolina Division of Coastal Management (DCM) and updated through 1992 are shown in Figure 9. These particular shoreline change rates were determined by comparing shoreline positions interpreted from 1938 and 1992 aerial photographs. The Corps of Engineers (USACE, 1989) determined shoreline change rates for North Topsail Beach by comparing the shoreline positions shown on a 1963 topographic map with shoreline positions interpreted from a 1983 aerial photo mosaic. The Corps recently updated shoreline change rates for North Topsail Beach using the 1963 topographic map and a 2002 topographic map developed for the Federal storm damage reduction feasibility study (USACE, 2004). The Corps 1963 to 1983 and 1963 to 2002 shoreline change rates are also shown in Figure 9.

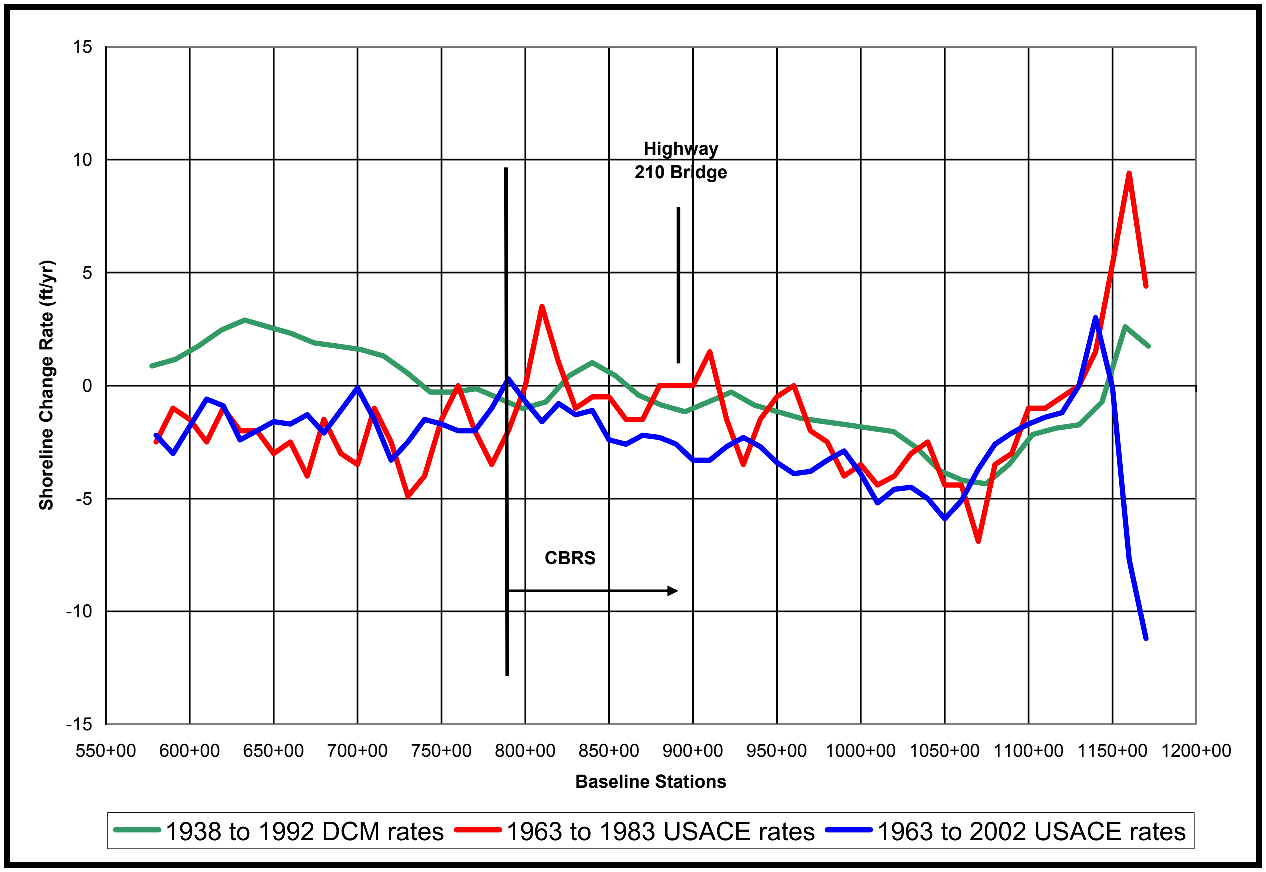


Figure 9. Comparison of shoreline change rates developed by the NC DCM for 1938 to 1992, USACE rates for 1963 to 1983, and USACE rates for 1963 to 2002.

The three sets of shoreline change data display similar trends; however, the DCM data indicate slightly lower rates of shoreline change along most of the Town's shoreline. For example, the DCM data for the non-CBRS area (baseline station 581+80 to approximately baseline station 785+00) indicated that the shoreline was advancing while the two sets of shoreline change data developed by the Corps of Engineers indicated recession in this area. All three sets of shoreline change information indicate an increase in shoreline recession rates from baseline station 810+00 northeast to around baseline station 1060+00 and then a general decrease in the recession rates from baseline station 1070+00 to around baseline station 1140+00. Between baseline station 1150+00 and New River Inlet, the shoreline change rates for the three data sets vary considerably due to the influence of New River Inlet.

The Corps of Engineers deposited over 154,000 cubic yards of maintenance dredge material from Cedar Bush Cut (channel connecting the AIWW with New River Inlet) from baseline station 1140+00 to station 1160+00 between 22 May and 2 July 2002, which may have artificially reduced the USACE 1963 to 2002 shoreline change rates in this area.

Estimated Shoreline Change Rates – 1983 to 2002

The shoreline change rates developed by the Corps of Engineers for the 1963 to 1983 and 1963 to 2002 time periods were used to estimate shoreline change rates between 1983 and 2002 to see if there has been any significant change in shoreline behavior. The shoreline change data for the 1963 to 1983 time period is compared to the estimated changes between 1983 and 2002 in Figure 10.

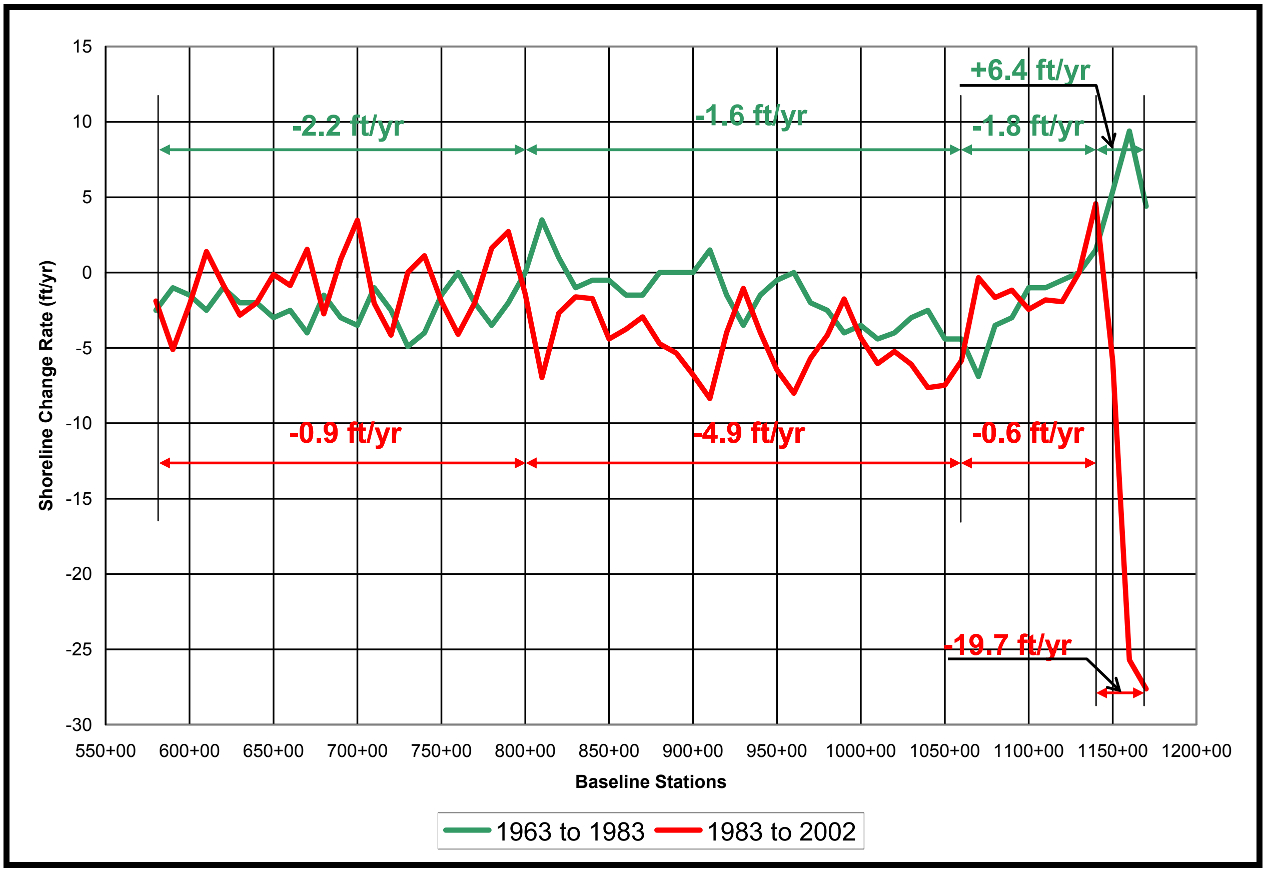


Figure 10. North Topsail Beach shoreline change rates, 1963 to 1983 and 1983 to 2002.

The average shoreline change rates for the area between baseline stations 580+00 and 800+00 appear to have decreased slightly during the 1983 to 2002 time period compared to the 1963 to 1983 time period. Between baseline stations 810+00 and 1060+00, shoreline change rates were almost three times greater during the 1983 to 2002 period compared to the 1963 and 1983 time period. The lower recession rate for the area between baseline stations 1070+00 and 1140+00 for the 1983 to 2002 time period may have been influenced by the southwest movement of the dredged material placed northeast of this area between May and July as mentioned above. In this regard, the dredged material moved out of the disposal area rather quickly with much of the material probably being dispersed toward the southwest under the influence of the predominant southwesterly sand transport. Shoreline change rates immediately southwest of New River Inlet (baseline stations 1140+00 to 1160+00) were dramatically different for the two periods with the shoreline advancing at an average rate of 6.4 ft/yr between 1963 and 1983 and retreating at an average rate of 19.7 ft/yr from 1983 to 2002. A more detailed analysis of shoreline changes in the vicinity of New River Inlet and the dependency of the shoreline behavior on New River Inlet are provided later in the sections associated with the development of inlet management plans.

BEACH PROFILES

Northern 7.25 miles

The Corps of Engineers conducted a beach profile survey along the entire length of Topsail Island in March 2002. The profile lines were generally spaced at 1,000-foot intervals. CPE surveyed the same beach profile lines within the northern 7.25 miles of North Topsail Beach in August 2005. Plots of the August 2005 profiles obtained by CPE between baseline stations 750+00 and 1140+00 are provided in Figures 11 to 18.

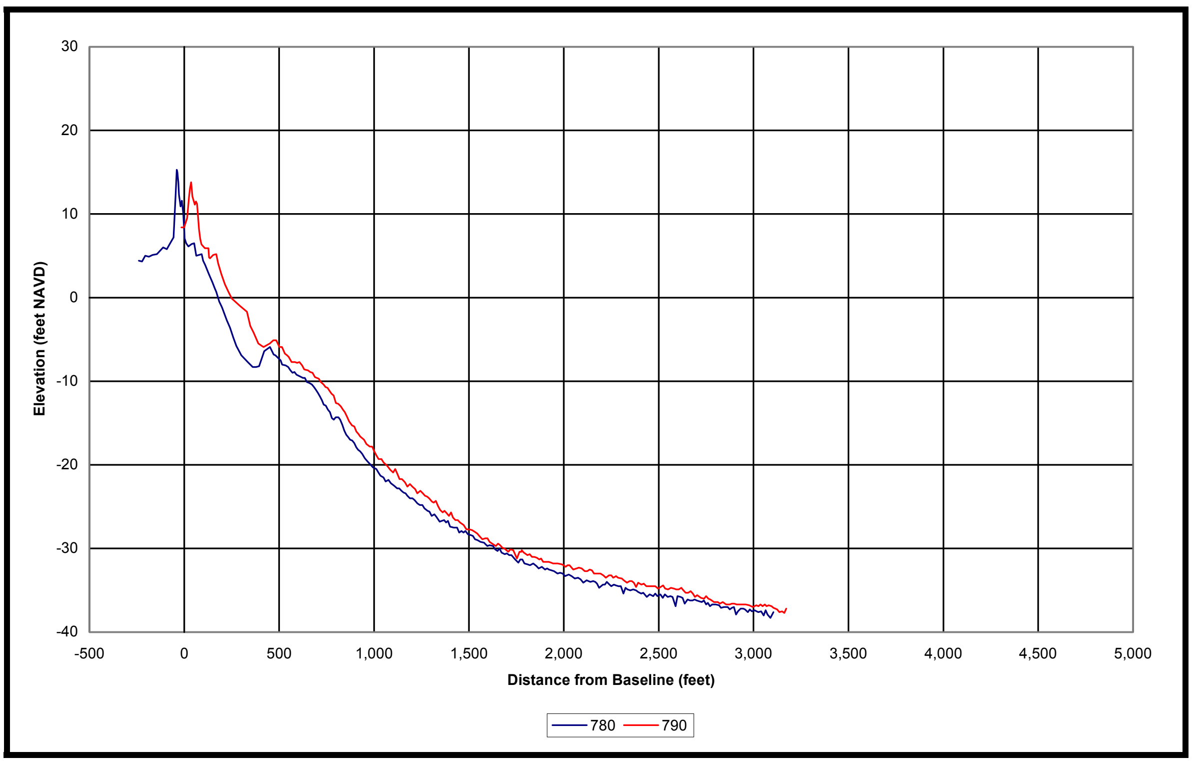


Figure 11. August 2005 beach profiles by CPE, baseline stations 780+00 to 790+00.

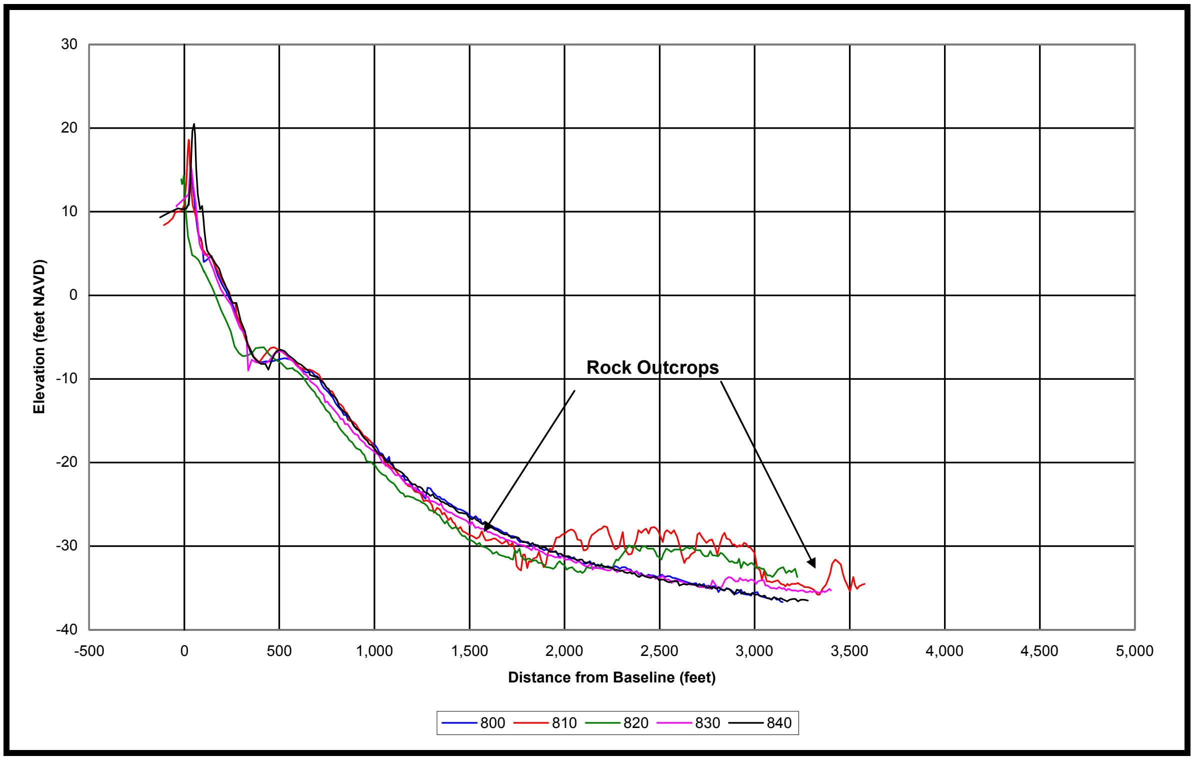


Figure 12. August 2005 beach profiles by CPE, baseline stations 800+00 to 840+00.

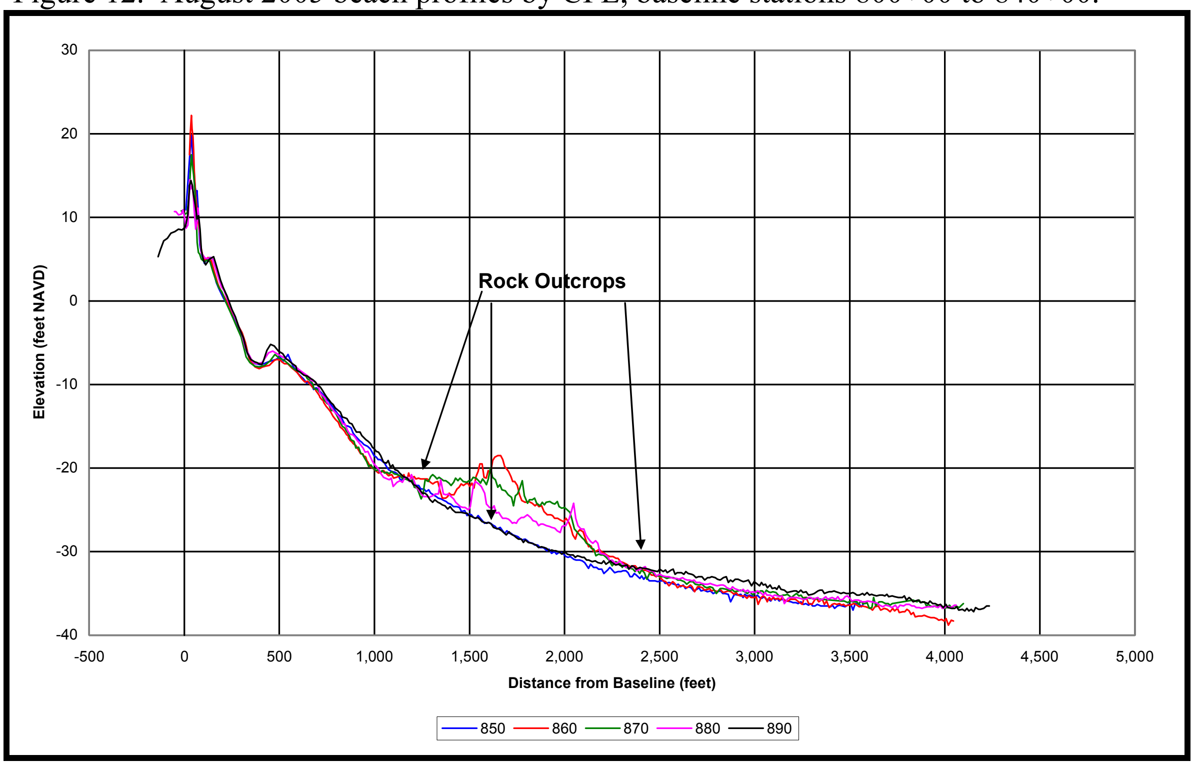


Figure 13. August 2005 beach profiles by CPE, baseline stations 850+00 to 890+00.

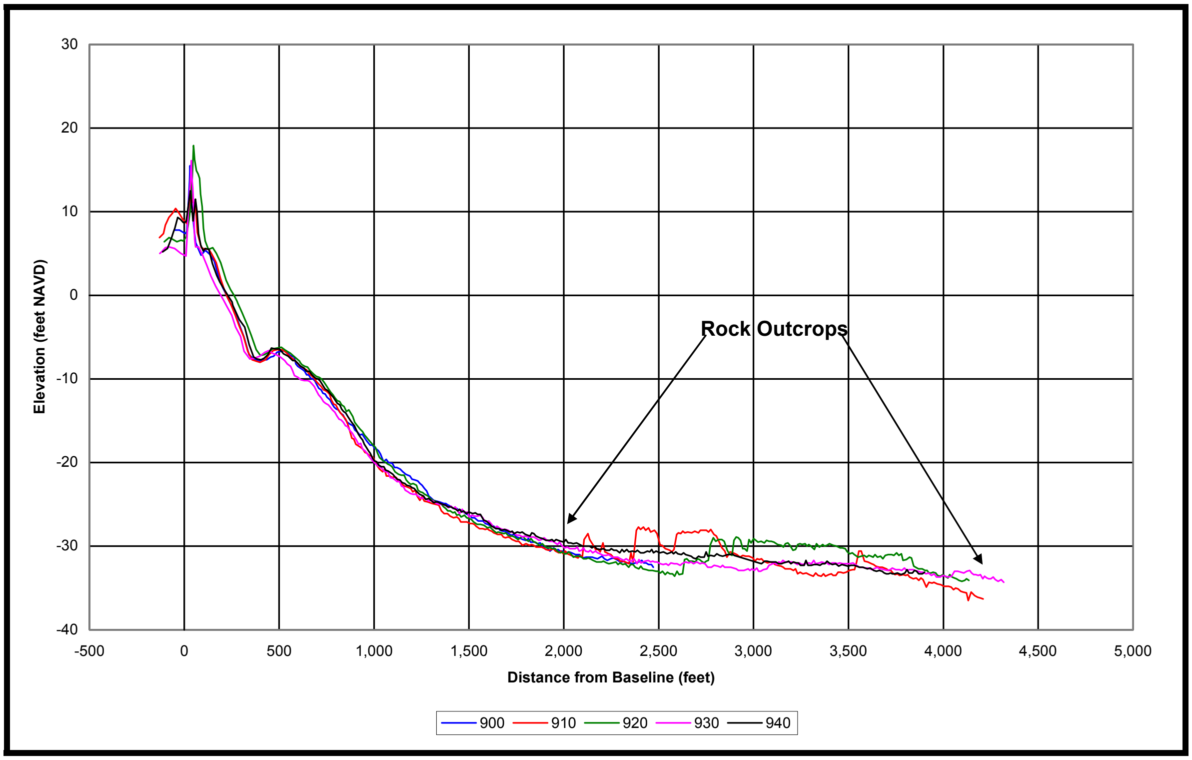


Figure 14. August 2005 beach profiles by CPE, baseline stations 900+00 to 940+00.

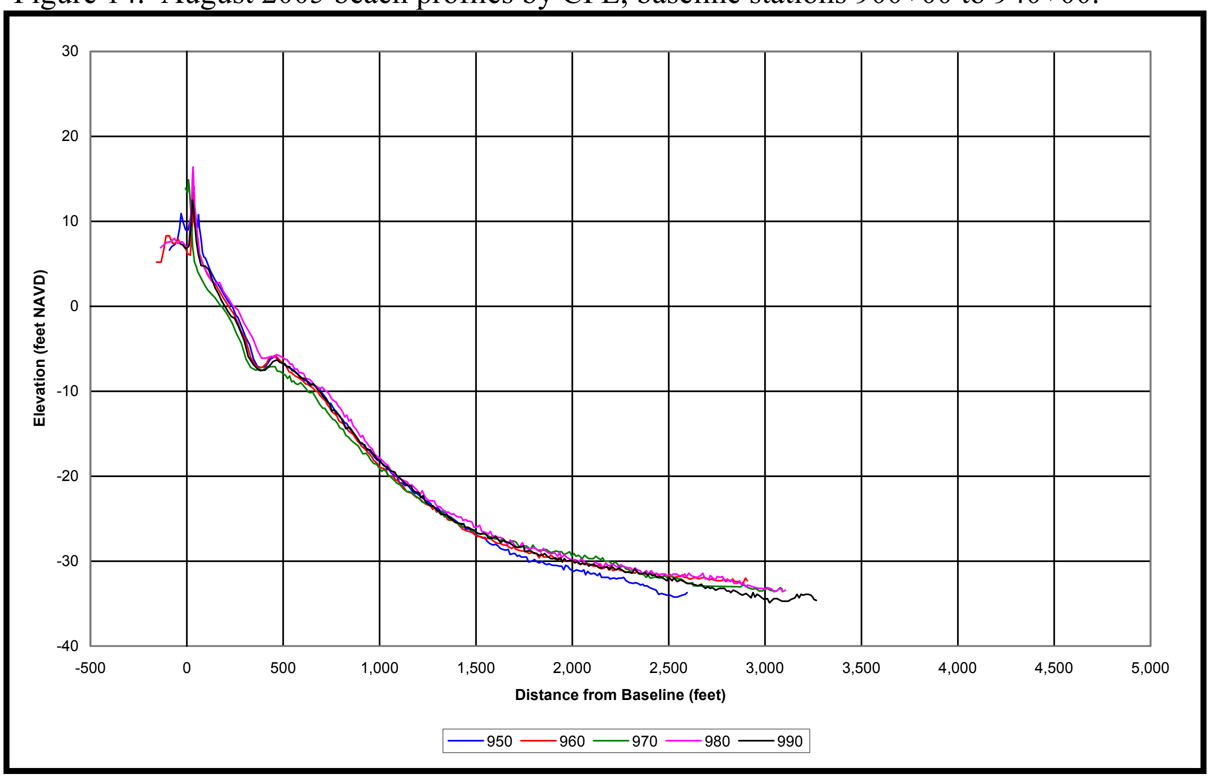


Figure 15. August 2005 beach profiles by CPE, baseline stations 950+00 to 990+00.

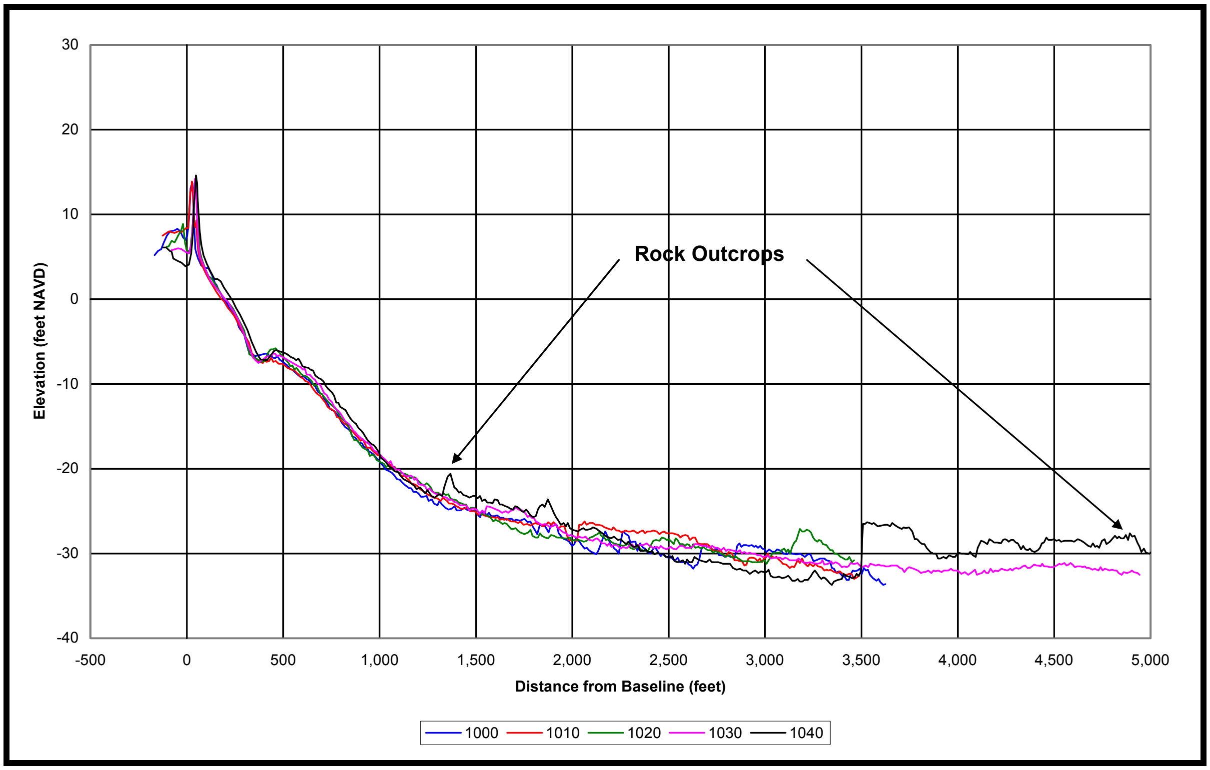


Figure 16. August 2005 beach profiles by CPE, baseline stations 1000+00 to 1040+00.

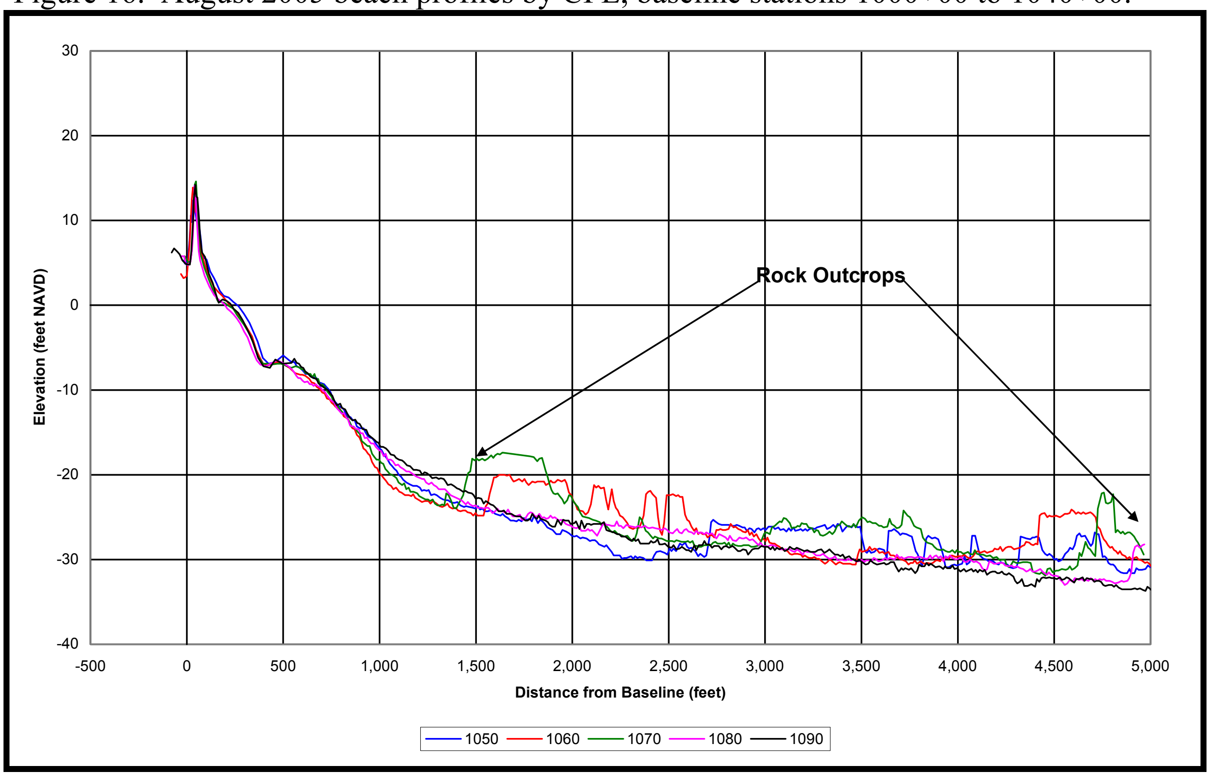


Figure 17. August 2005 beach profiles by CPE, baseline stations 1050+00 to 1090+00.

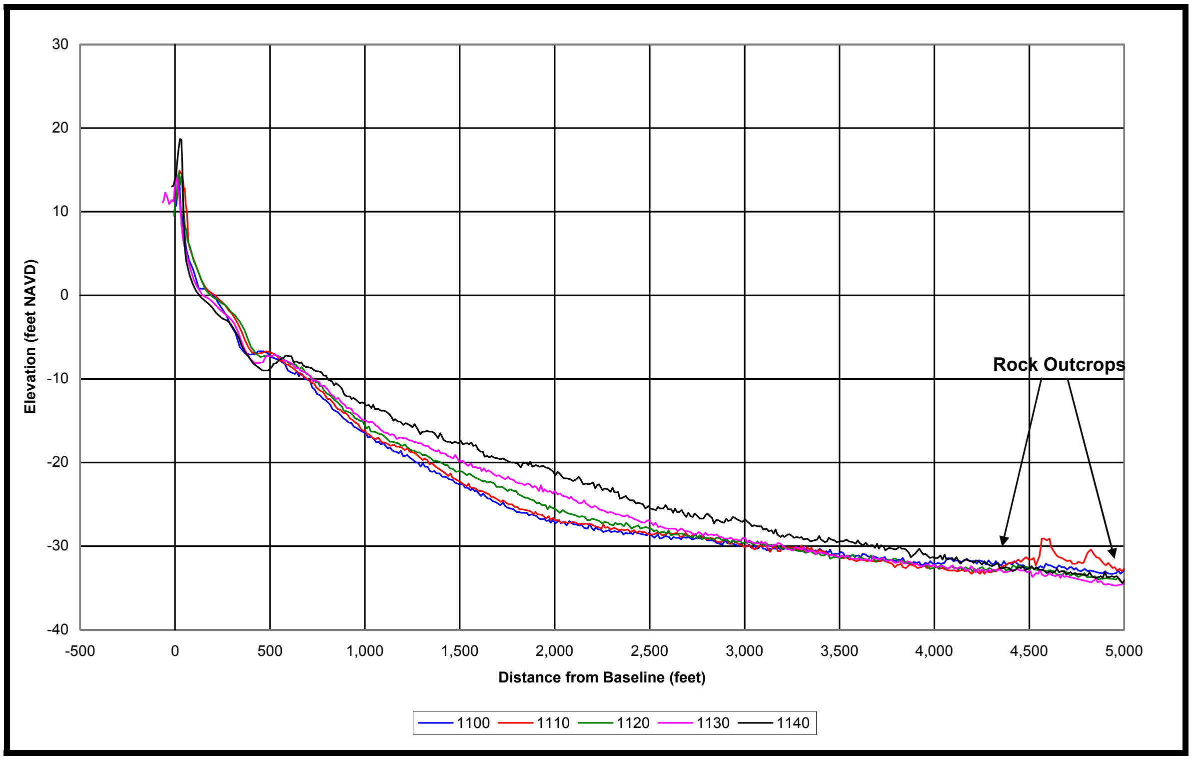


Figure 18. August 2005 beach profiles by CPE, baseline stations 1100+00 to 1140+00.

Nearshore Hardbottoms – Northern 7.25 miles

The August 2005 profiles show the existence of rock outcrops and scarps offshore of the northern reaches of North Topsail Beach. The existence of these nearshore hardbottom areas has been previously identified by Cleary, McLeod, Rauscher, Johnson, and Riggs (2000) and were also evident on the Corps March 2002 profiles. The rock outcrops appear in water depths of around -20 feet NAVD between baseline stations 810+00 and 890+00 and between baseline stations 1020+00 to 1090+00. Along other sections of the northern 7.25 miles of North Topsail Beach, the outcrops occur farther offshore with their landward edges in water depths of -30 feet NAVD or deeper.

Sidescan Survey – Northern 7.25 miles

CPE conducted a sidescan sonar survey of the nearshore area to obtain a two-dimensional definition for the location of the nearshore hardbottom resources. The tracklines of the sidescan survey are shown in Figure 19.

The location and extent of the nearshore hardbottom areas identified by the sidescan survey are shown in Figures 20A to 20B along with the position of the point of intercept or the estimated toe of fill. The sidescan survey confirmed the existence of nearshore hardbottoms just offshore of the Hampton Colony development (baseline stations 810+00 to 890+00 in Figure 20B) and between baseline stations 1020+00 to 1090+00 (Figure 20A).

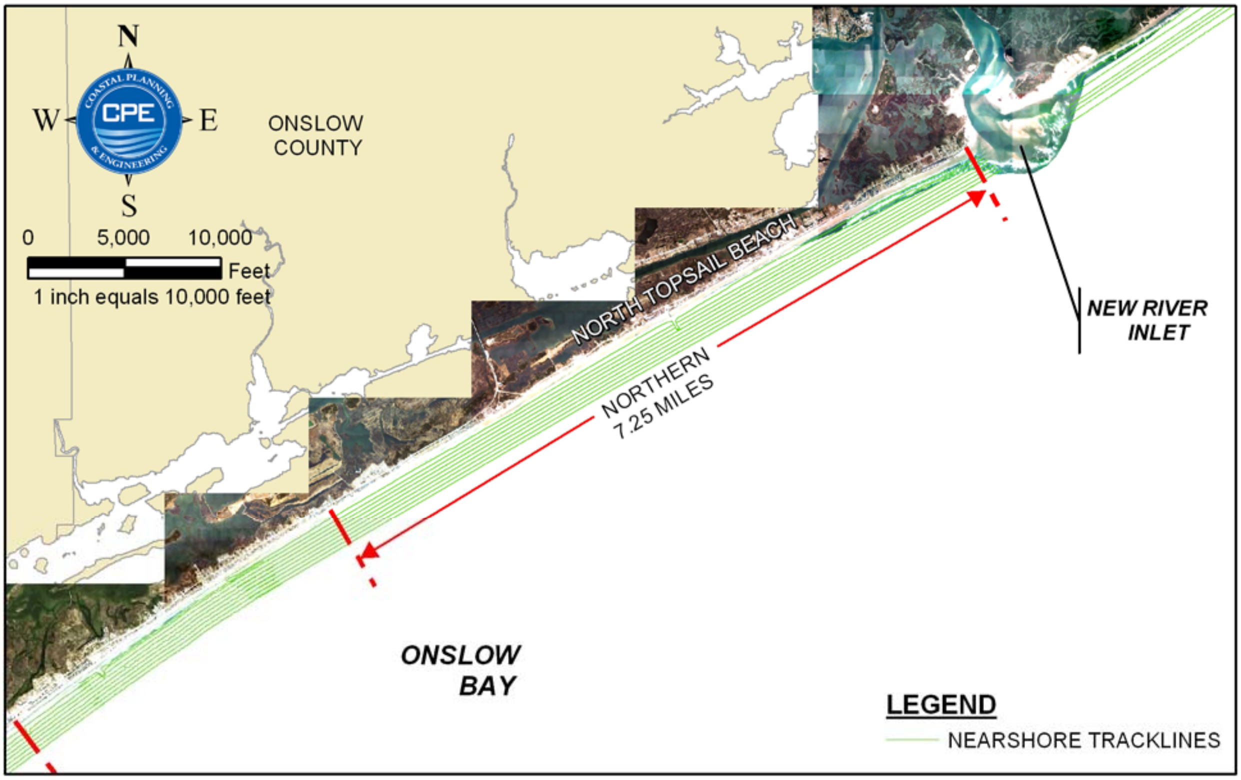


Figure 19. CPE sidescan sonar tracklines.

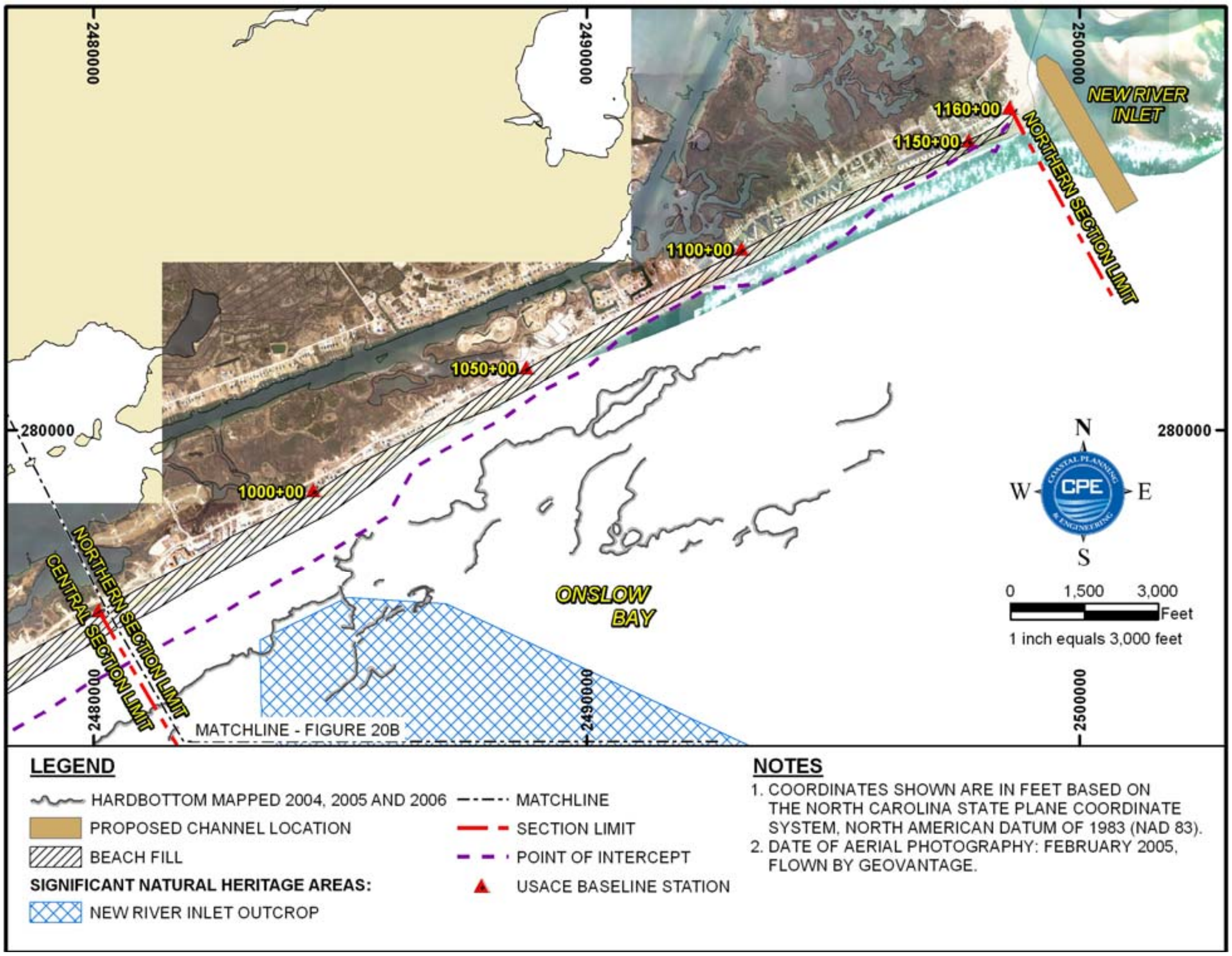


Figure 20A. Location of nearshore hardbottom areas identified by the sidescan survey, northern 7.25 miles.

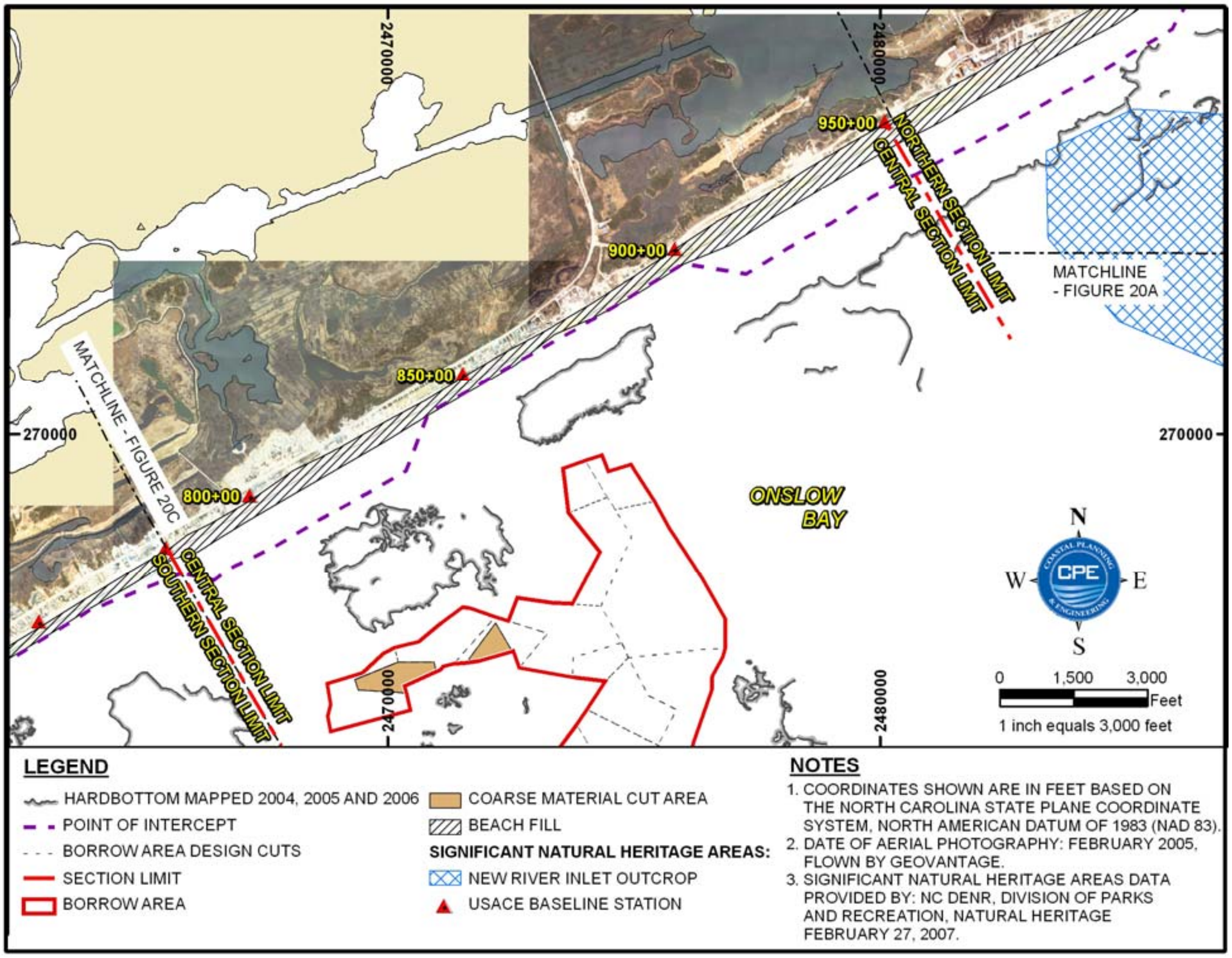


Figure 20B. Location of nearshore hardbottom areas identified by the sidescan survey, northern 7.25 miles.

Southern 3.85 miles

CPE conducted a beach profile survey along the southern 3.85 miles of North Topsail Beach in October 2006, covering the same 1,000-foot profile lines surveyed by USACE in March 2002. The results of the CPE profile survey are provided in Figures 21 to 24.

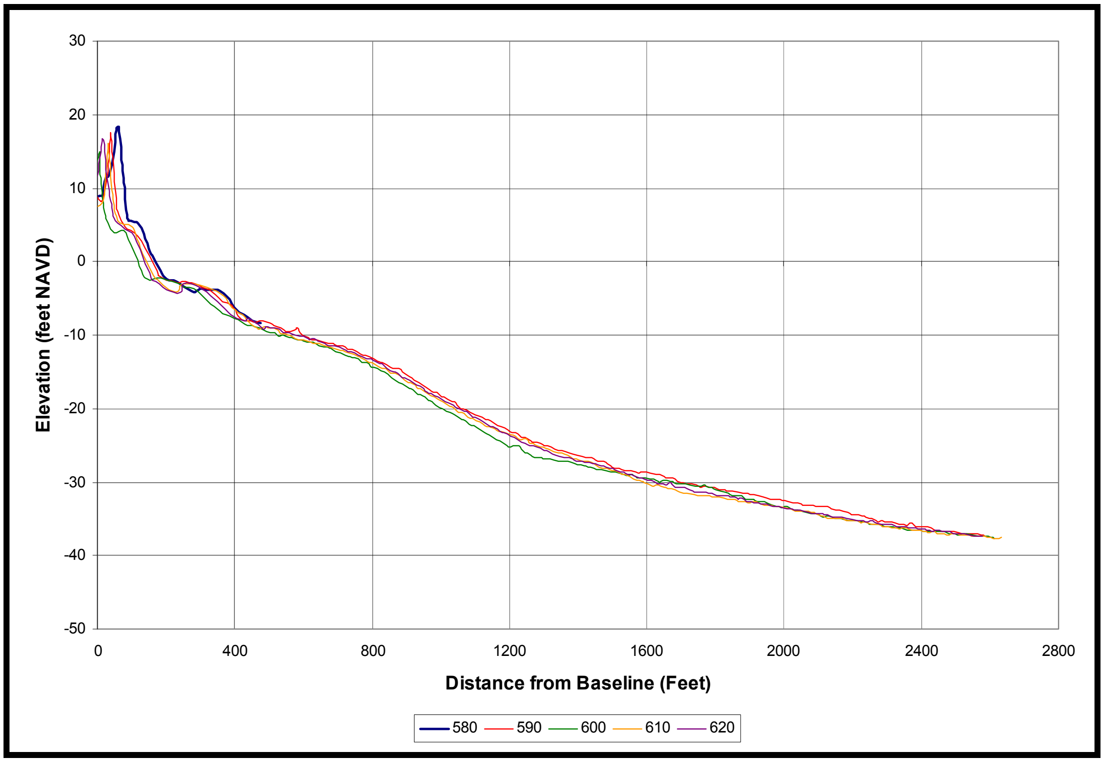


Figure 21. October 2006 beach profile survey by CPE, stations 580+00 to 620+00.

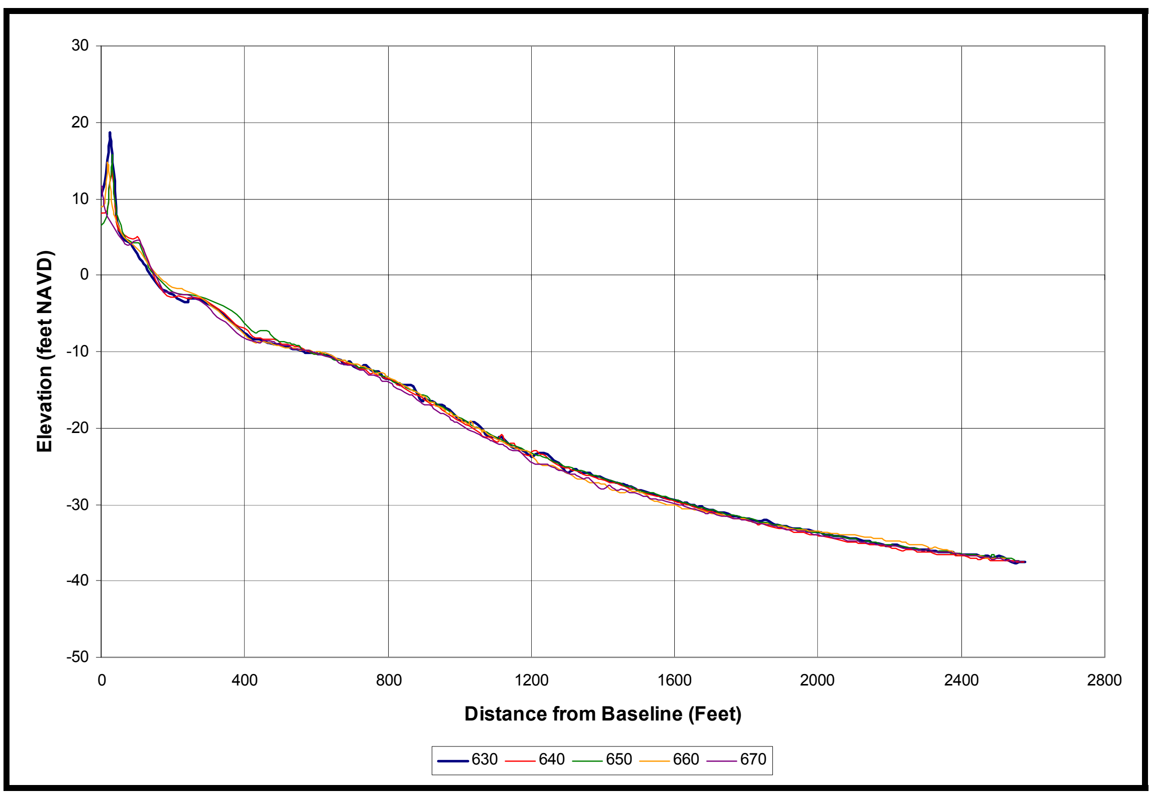


Figure 22. October 2006 beach profile survey by CPE, stations 630+00 to 670+00.

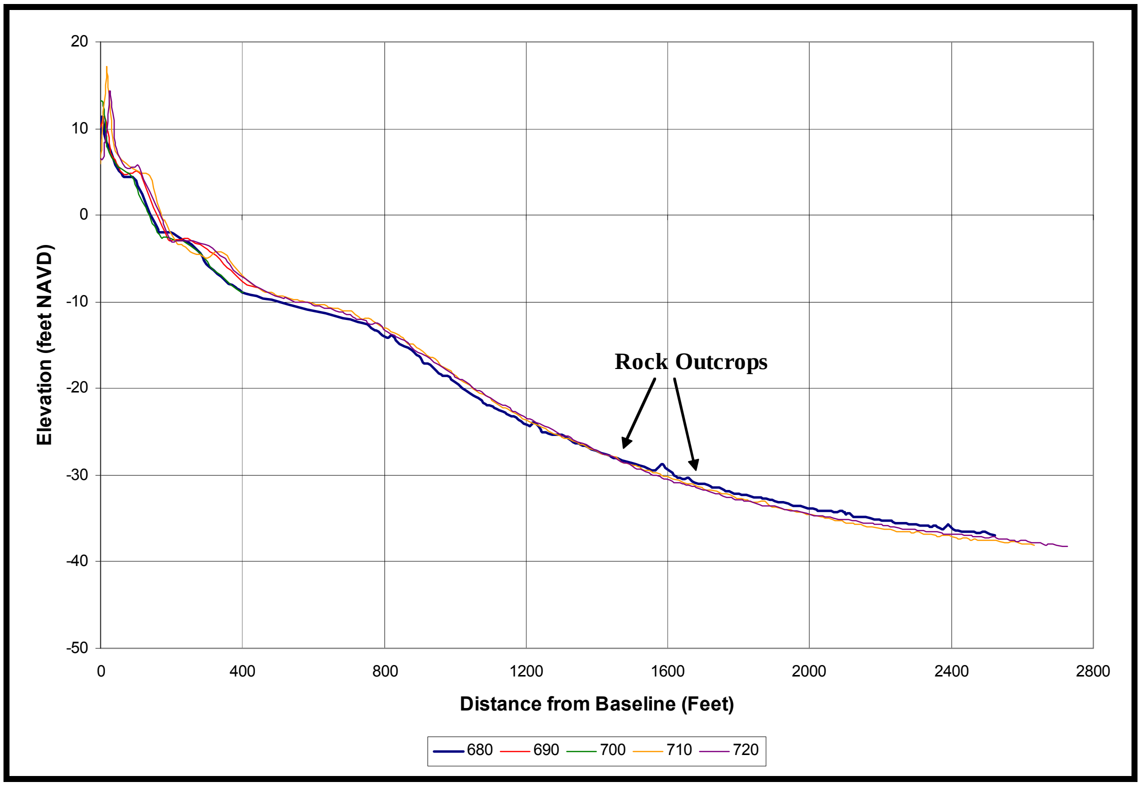


Figure 23. October 2006 beach profile survey by CPE, stations 680+00 to 720+00.

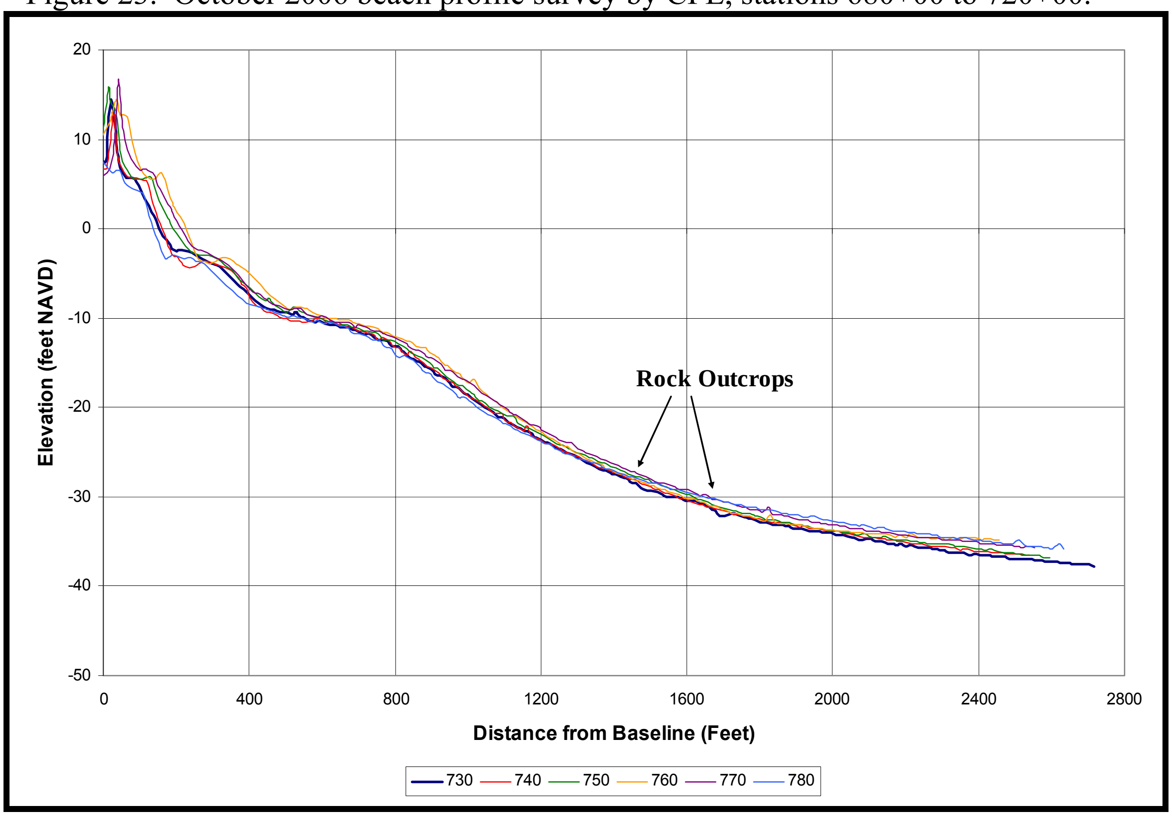


Figure 24. October 2006 beach profile survey by CPE, stations 730+00 to 740+00.

Nearshore Hardbottom – Southern 3.85 miles

The beach profile survey did not indicate the presence of prominent nearshore rock outcrops along the southern 3.85 miles of the North Topsail Beach shoreline. The only noticeable outcrop was approximately 1500 feet offshore along profile lines 720+00 (Figure 23) and 730+00 (Figure 24). The location and extent of the nearshore hardbottom areas identified by the sidescan survey in the southern 3.85 miles are shown in Figure 25 along with the position of the point of intercept.

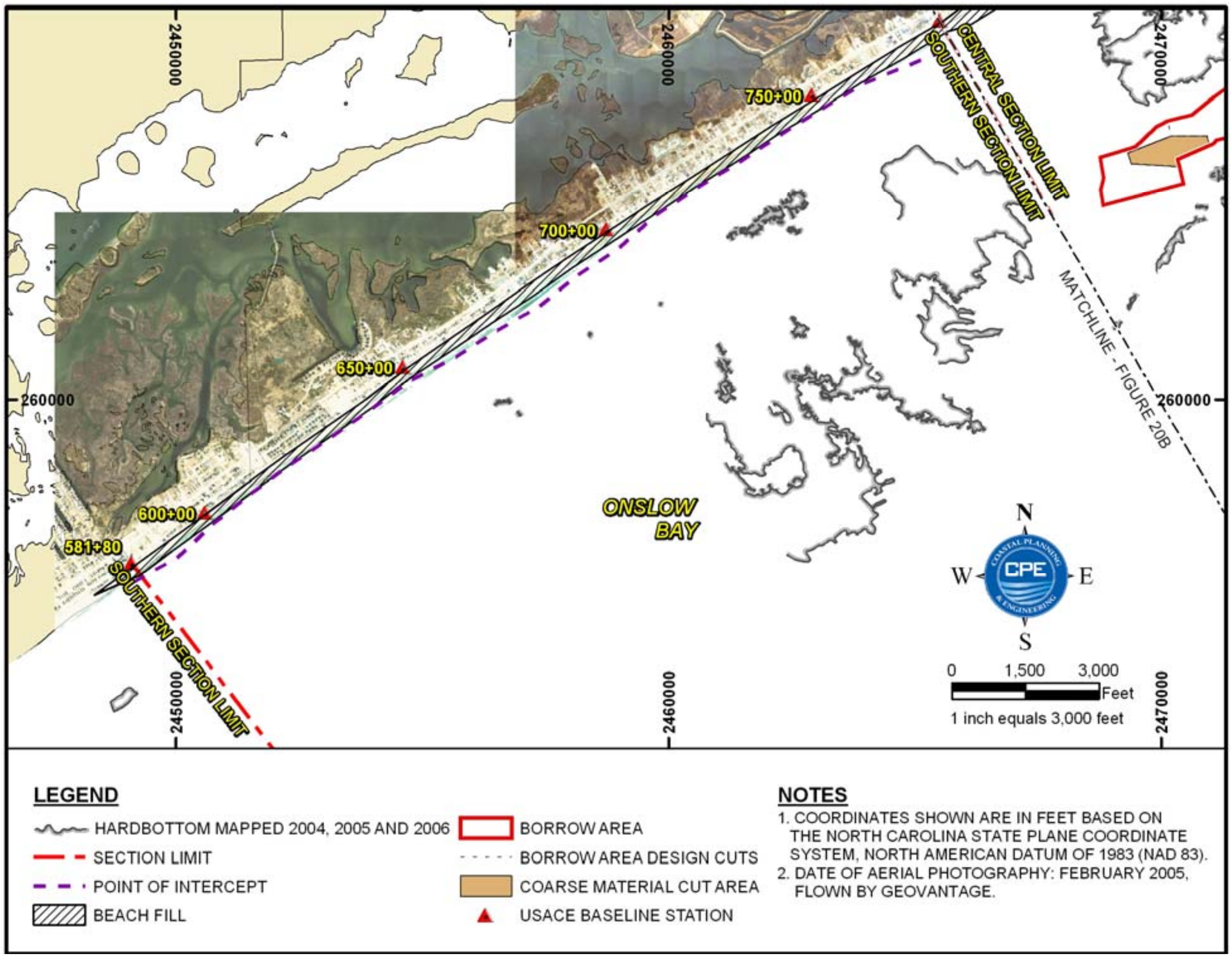


Figure 25. Location of nearshore hardbottom areas identified by the sidescan survey, southern 3.85 miles.

CHARACTERISTICS OF THE NATIVE BEACH MATERIAL

Corps of Engineers Native Beach Sediment Samples

Samples of the native beach material were obtained by the Corps of Engineers in August 2003 from grab sample profiles 13 to 24 shown in Figure 26. The locations of the grab sample profiles relative to the baseline are shown later in this section in Table 3. A total of 17 samples were collected from each profile from the toe of the dune seaward to -25 feet, NAVD, with samples collected at approximately 2-foot depth intervals. All of the samples were analyzed for their grain size distributions using standard sieve analysis from which the mean particle size and standard deviation were determined.

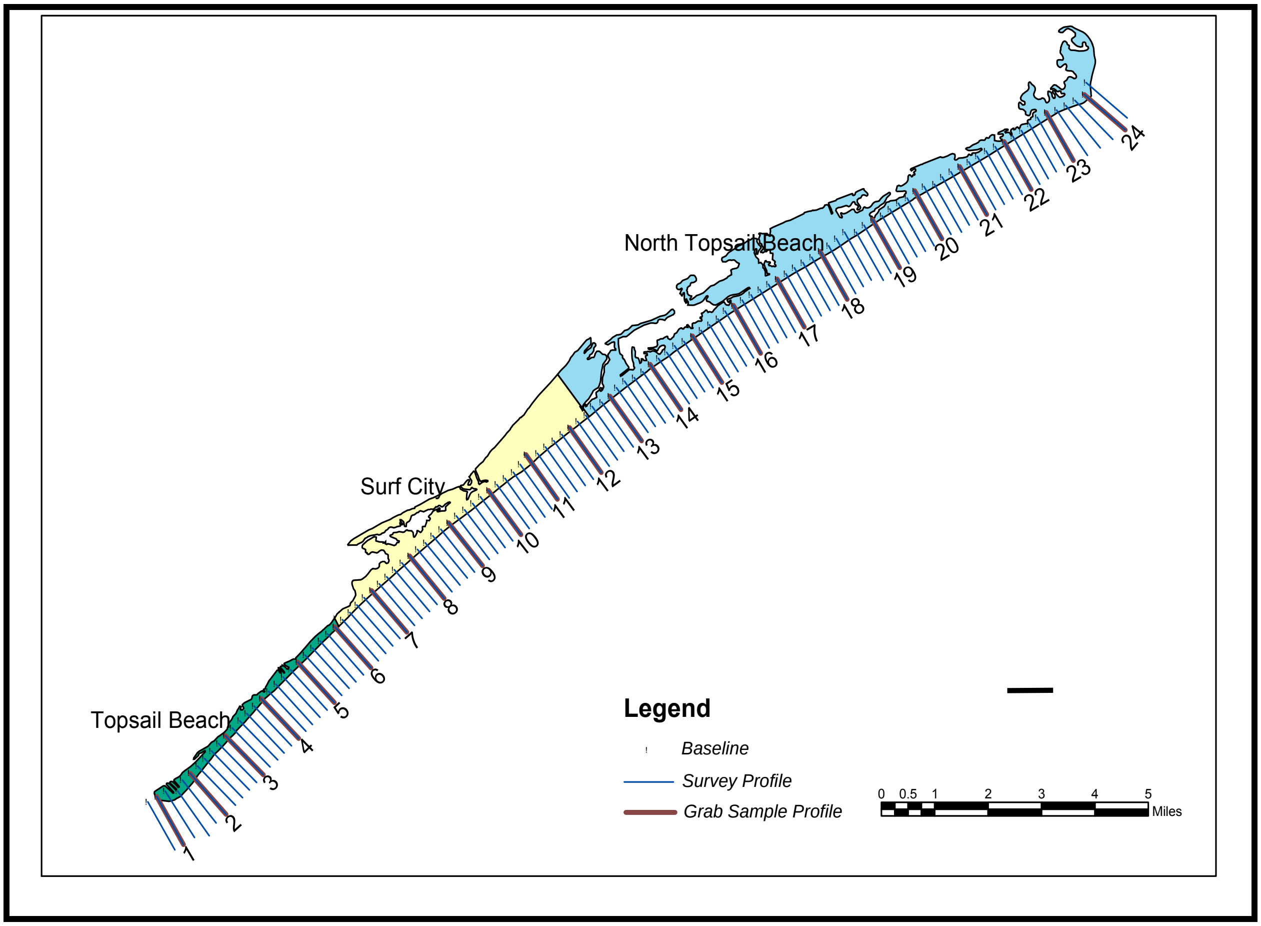


Figure 26. Location of native beach grab sample profiles (Figure provided by the Wilmington District Corps of Engineers).

The average mean particle size and the average standard deviation for all samples collected at the various points on each of the 12 profiles are plotted versus the sample depth in Figure 27. The mean particle size is given in millimeters (mm) while the standard deviation is expressed in phi (φ) units where:

$$\varphi = -\ln(d)/\ln(2)$$
$$d = \text{grain size in mm}$$

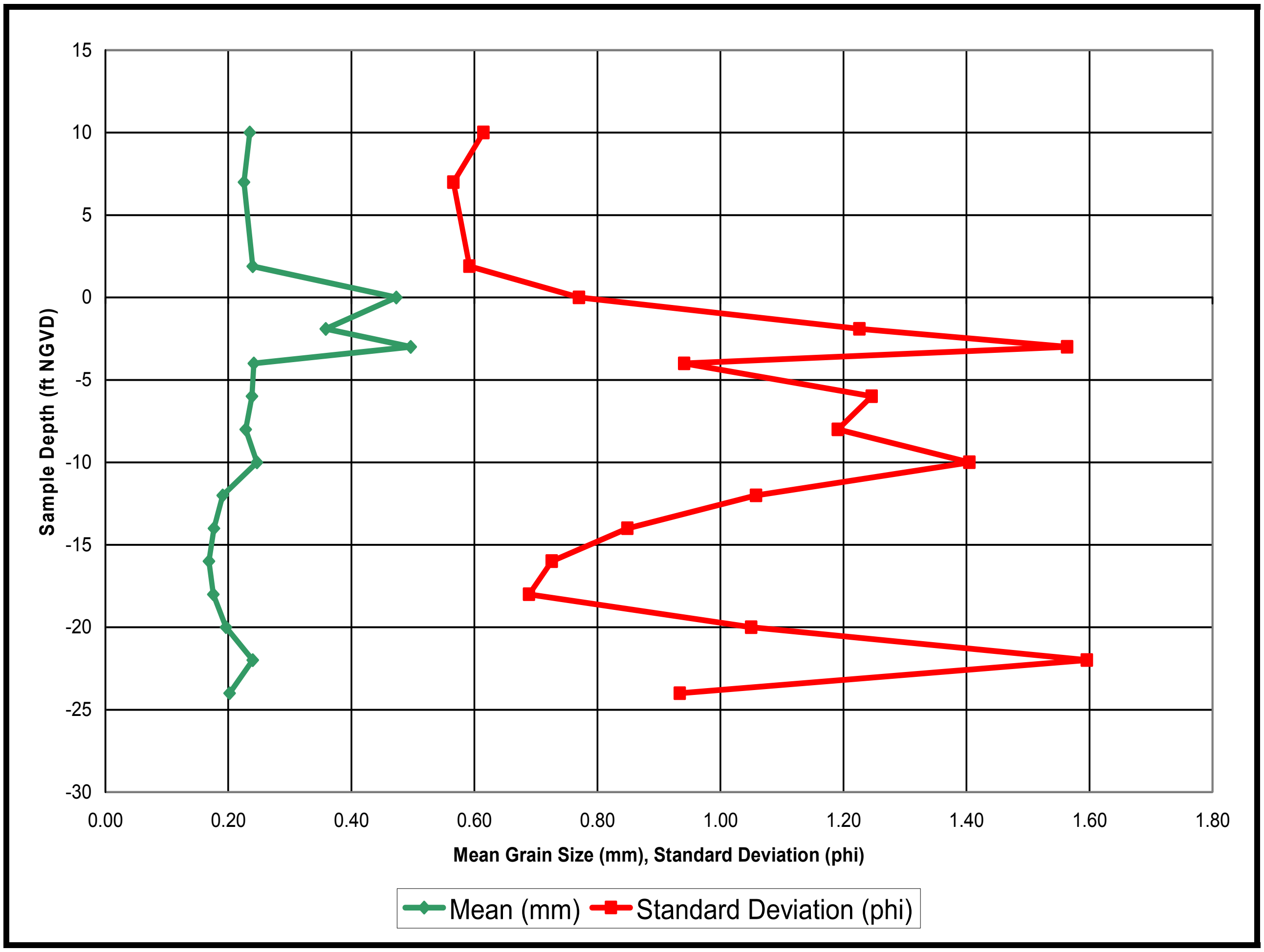


Figure 27. Native grain size characteristics versus surface sample depth.

Composite Characteristics of Native Beach Material

The mean particle size variation with depth on North Topsail Beach is fairly typical of other beaches in North Carolina in which the coarser material is found in the more turbulent foreshore area, which extends from the mean high water (+1.4 ft NAVD) down to around -4 to -5 feet NAVD. Seaward of this relatively high wave energy area, the mean particle size on North Topsail Beach decreases seaward to a depth of around -15 to -21 feet NAVD and then appears to increase seaward of these depths.

The standard deviation of the particle size distributions also shows a strong dependency on depth with relatively large standard deviations in the foreshore area seaward to a depth of -11 feet NAVD with the standard deviation decreasing from this point out to a depth of around -19 feet NAVD. The magnitude of the standard deviations again increase seaward of the -19-foot NAVD depth. The increase in the mean grain size and standard deviation of the individual samples collected seaward of -19 feet NAVD appeared to result from the intermixing of the beach quality material with rock fragments and shell hash that had been dislodged from the adjacent hard bottom areas. Due to this apparent intermixing of materials in the deeper portions of the profiles, the composite characteristics of the native beach material was based on the samples collected between the crest of the normal beach berm (approximately +6.0 feet NAVD) seaward to a depth of -19 feet NAVD.

The grain size distributions of samples collected from each of the 12 profiles out to a depth of -19 feet NAVD were combined and the average grain size distribution characteristics for each profile determined. The average grain size distributions for the 12 profiles were then combined to determine the composite grain size distribution for North Topsail Beach. Table 3 provides a summary of the average grain size characteristics for each profile along with the overall composite distribution for North Topsail Beach. The composite grain size characteristics that will be used to determine the compatibility of the borrow material are:

Mean (phi units) =	$M_\varphi = 2.17$ phi
Mean (mm) =	$M = 0.22$ mm
Standard Deviation =	$S_\varphi = 1.02$ phi
% Gravel ($d \geq 4.76$ mm) =	0.8%
% $4.76 > d > 2$ mm =	1.7%
% $d \geq 2$ mm =	2.5%
% Silt ($d \leq 0.063$ mm) =	2.9%
Shell Content =	8.4%

Table 3. Characteristics of the native beach material, North Topsail Beach, NC.

Grab Sample Profile	Baseline Profile Number	Mean (phi units) (M_φ)	Mean (mm)	Standard Deviation (phi units) (S_φ)	% Shell	% $d \geq 4.76$ mm	% 4.76mm to 2mm	% $d \geq$ 2mm	% Silt $d \leq$ 0.063 mm
TB-13	606+51	2.10	0.23	0.90	9.8	0.4	1.1	1.5	2.2
TB-14	657+36	2.23	0.21	0.75	6.7	0.1	0.4	0.5	1.9
TB-15	707+38	2.07	0.24	1.03	9.1	0.7	1.6	2.3	2.0
TB-16	757+62	2.03	0.24	1.12	9.3	0.8	2.1	2.9	2.2
TB-17	807+57	2.23	0.21	1.04	10.1	1.1	2.1	3.2	3.1
TB-18	857+54	2.35	0.20	0.75	5.9	0.2	0.9	1.0	1.9
TB-19	919+60	2.07	0.24	1.06	10.5	0.9	1.8	2.7	2.9
TB-20	970+00	2.15	0.23	1.15	6.2	0.7	2.5	3.2	4.4
TB-21	1020+75	2.17	0.22	1.17	7.4	1.8	2.4	4.2	3.5
TB-22	1070+77	2.17	0.22	1.07	11.3	1.5	2.0	3.5	2.9
TB-23	1120+93	2.23	0.21	1.11	10.1	1.1	3.3	4.4	5.5
TB-24	1162+46	2.29	0.20	0.68	4.7	0.6	0.3	0.9	1.9
Composite NTB		**2.17**	**0.22**	**1.02**	**8.4**	**0.8**	**1.7**	**2.5**	**2.9**

The classification of the native beach material as gravel or silt is based solely on the size of the material, not its chemical composition. Accordingly, some of the gravel size material on the existing beach could be shell or shell hash that is equal to or larger than 4.76 mm.

BORROW AREA GEOTECHNICAL INVESTIGATIONS

Proposed New State Standards for Borrow Material

The North Carolina Coastal Resources Commission (CRC) adopted new standards for borrow material aimed at preventing the disposal of an inordinate amount of coarse material (primarily shell and shell hash) on the beach. The new standards limit the amount of material in the borrow area with a diameter equal to or greater than 4.76 mm (gravel) to no more than 5% above that which exists on the native beach. In the case of North Topsail Beach, which has an average gravel content of 0.43% (Table 3), the upper limit of gravel in the borrow area is 5.43%. The new State standards also limit the amount of silt (sediment size equal to or less than 0.0625 mm) to 5% above the native beach material. For North Topsail Beach, the allowable silt content in the borrow area is therefore 6.5%. Presently, Federal standards allow 10% fines in the borrow area. Finally, the State sediment standards limit calcium carbonate (shell) to no more than 15% above that of the native beach. For North Topsail Beach, the borrow area shell (calcium carbonate) content would be limited to 40.83%. The new State standards were used to guide the selection of suitable borrow areas for the North Topsail Beach project.

Scope of Investigations

The search for compatible borrow material for the construction of the North Topsail Beach project concentrated on areas lying 1 to 3 miles offshore. Also, geotechnical investigations were also conducted in New River Inlet to determine the quality of material that would be removed to construct the new channel and determine its compatibility with the native beach material.

The offshore geotechnical investigations were conducted in two phases. The first phase occurred during the summer of 2005 and was focused on finding compatible material to construct the beach fill project along the northern 7.25 miles of the Town's shoreline that is within the CBRS. With the addition of the South Section in May 2006, offshore geotechnical investigations were conducted during the summer of 2006 to expand the offshore borrow area to include a volume of suitable material to support the initial construction of the entire 11.1 mile long project.

The Corps of Engineers (USACE) conducted preliminary subsurface investigations offshore of all of Topsail Island in 2003 as part of the Federal feasibility study. The results of the Corps' preliminary investigation were used by CPE to focus on areas that had the greatest potential to satisfy beach nourishment requirements. Figure 28 shows the locations of USACE vibracores, seismic tracklines, and the locations of the CPE sand search investigations. Investigations were conducted in two areas: North and South Target areas. The North Target area was later eliminated as a viable source of large quantities of beach quality material. The complete description of the Geotechnical Investigations and results can be found in Appendix I – Geotechnical Investigations.

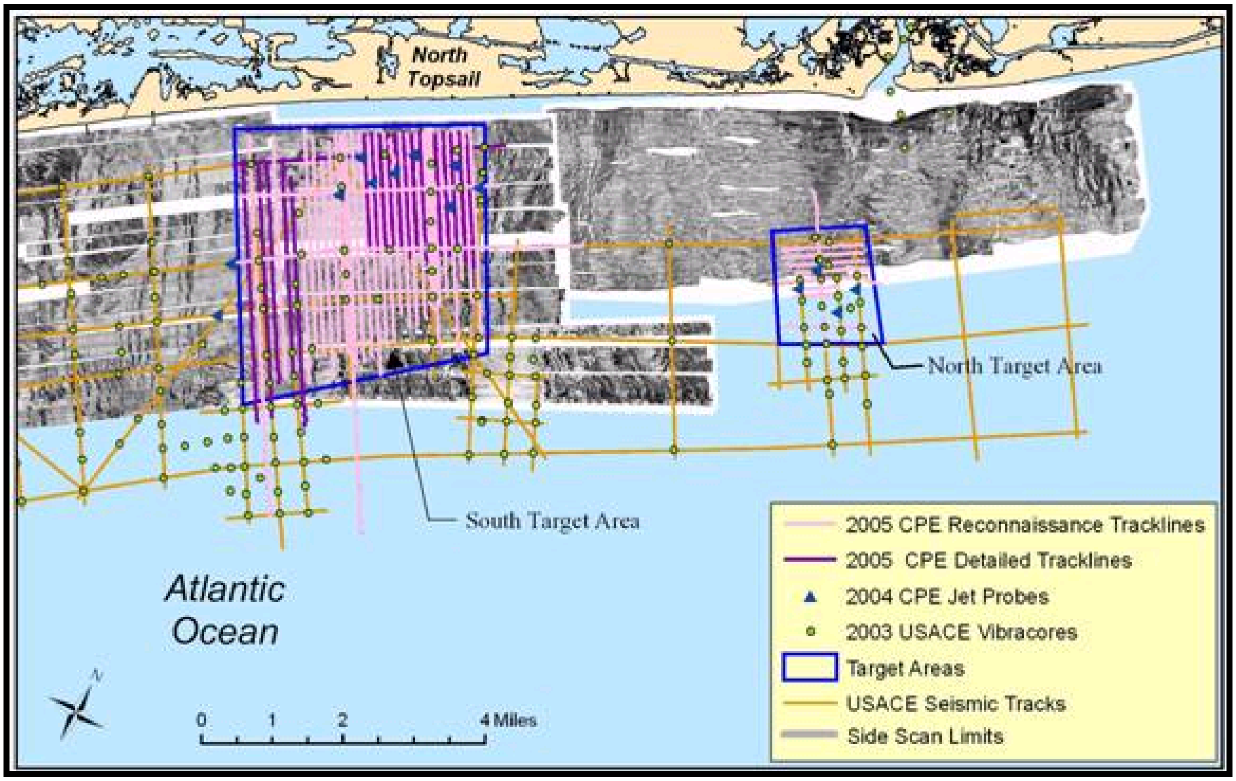


Figure 28. Location of CPE and Corps of Engineers vibracores, jet probes, and seismic tracklines.

The seismic record in conjunction with the sidescan survey, which showed the location of exposed hardbottoms and rock outcrops, were used to define an irregularly shaped borrow area. The location and outline of the potential borrow area is shown in Figure 29. The outlines of the 21 individual subareas and their maximum depths of cut and vibracore locations are shown in Figure 30. Sand samples from distinct sediment layers in each vibracore were analyzed by mechanical sieving and the composite grain size characteristics (mean grain size, sorting coefficient, silt content, and shell content) of each vibracore determined. A summary of the composite grain size characteristics for the coarse and fine material in the offshore borrow area and the New River Inlet material are in Table 4. The total volume of material available in the offshore Borrow Area is 6,551,000 cubic yards, including both fine and coarse fill. Approximately 635,800 cubic yards are proposed for dredging from within New River Inlet (discussed later).

Table 4. Composite Grain Size Characteristics

	Grain Size (mm)	Sorting	% Silt	% Carbonate	% Granular	% Gravel
NATIVE BEACH	0.23	0.94	1.5	25.83	1.07	0.43
State Standard Allowance	-	-	5.0	15.0	5.0	5
State Standard Cutoff	-	-	6.5	40.83	6.07	5.43
Offshore BA (fine)	0.21	1.02	6.4	15.81	1.13	1.43
Offshore BA (coarse)	0.33	0.57	1.75	20	0.63	0.0
Channel BA	0.32	1.19	1.15	15.71	3.05	1.8

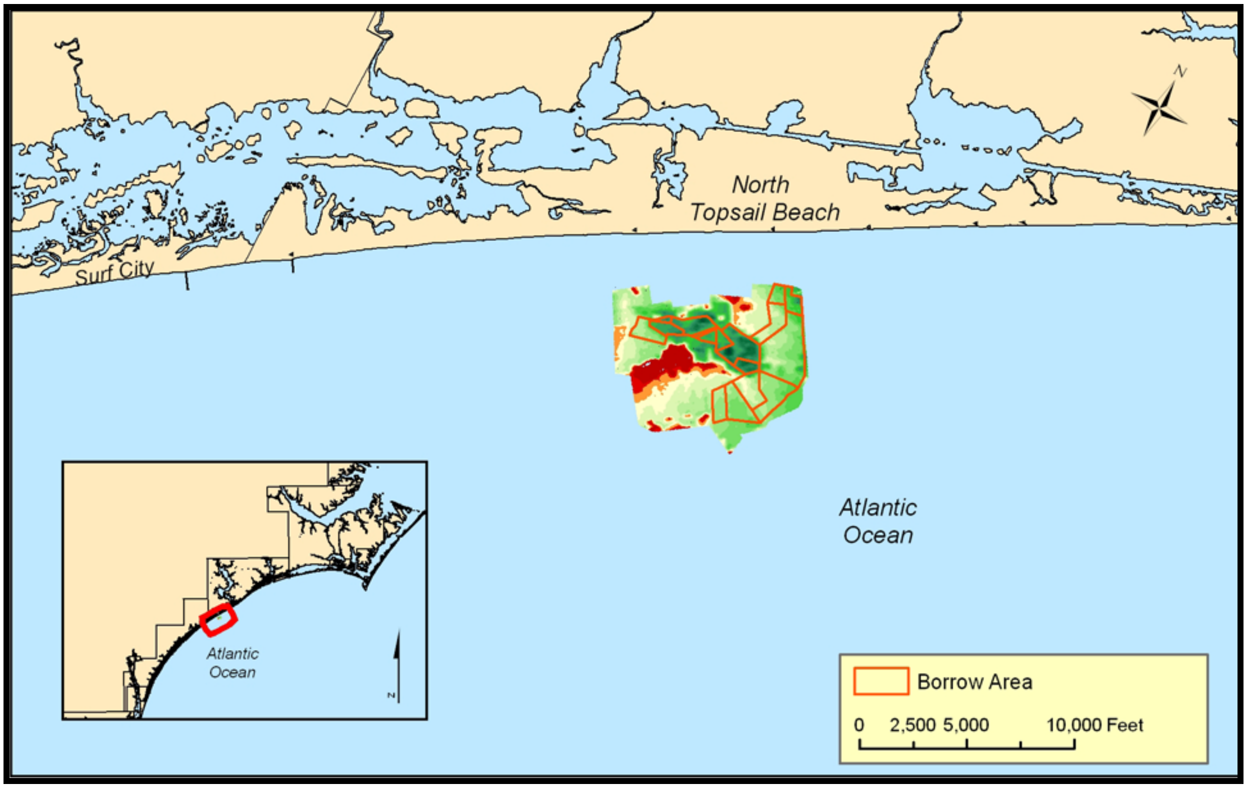


Figure 29. Location of proposed Borrow Area.

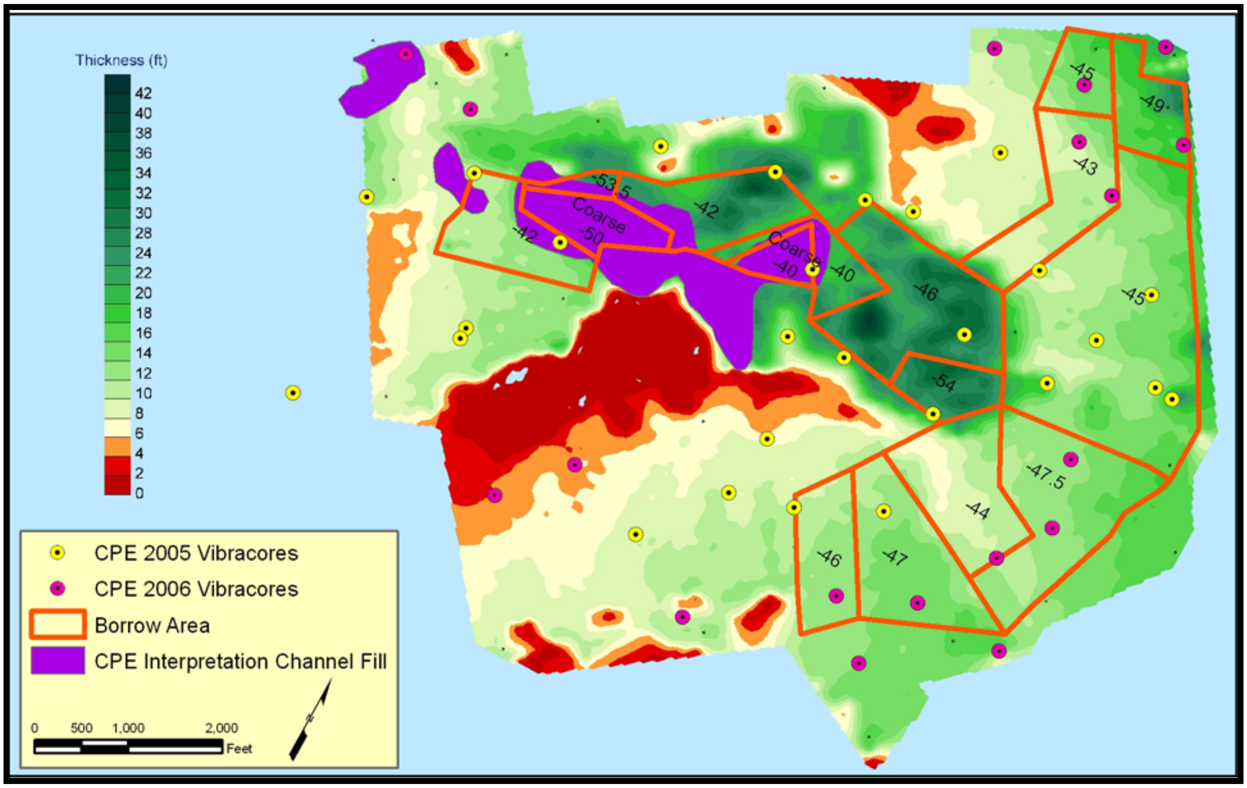


Figure 30. Borrow area isopach of sand thickness showing subareas, maximum cut depths, and vibracore locations.

INLET MANAGEMENT PLAN

Background

The ebb tide delta, also known as the ocean bar, of New River Inlet has experienced significant changes in its configuration over the last 20 years that have negatively impacted shoreline stability along the north end of North Topsail Beach. The changes in the configuration of the ocean bar are associated with shifts in the position and orientation of the main channel (ebb tide channel) that cuts across the ocean bar. When the main channel moves north, the ebb shoal provides less protection for the north end of North Topsail Island and severe erosion is experienced.

New River Inlet is not a natural inlet because its physical condition has been substantially altered by the construction and maintenance of several navigation channels including the AIWW and a channel connecting the AIWW with the Atlantic Ocean through the inlet's ocean bar. The existence of a navigation channel across the ocean bar presents opportunities to develop a more effective sand management plan for the inlet that will benefit not only the adjacent beaches but navigation interests as well.

Inlet Management Plan

The inlet management plan involves the repositioning of the main channel through the ebb tide delta of New River Inlet to a more favorable position so that negative impacts of the inlet on the adjacent shorelines on North Topsail Beach and Onslow Beach are reduced. The new channel would require periodic dredging to maintain the preferred position and alignment.

Inlet Investigations

Investigations conducted to gain a better understanding of the relationships between the inlet and its impacts on the adjacent shorelines and develop a design for the proposed new bar channel are summarized below. These investigations include: (a) a review of navigation improvements that have had an impact on the hydraulics of the inlet, (b) an evaluation of the geomorphic history of the inlet and adjacent shorelines, (c) development of a sediment budget to relate how material moves into and across the inlet, (d) a numerical model to evaluate changes in flows and circulation patterns that would be associated with modification of the inlet channel, and (e) an estimate of the shoaling expected in the new repositioned and enlarged inlet bar channel.

Navigation Improvements

The hydraulics of New River Inlet has been altered over the years due to the construction and maintenance of several navigation projects. The AIWW was constructed in the early 1930's behind New River Inlet (Figure 31). The AIWW has authorized dimensions of 90 feet wide at a depth of 12 feet below mean low water (MLW) or approximately 15 feet below NAVD. The AIWW hydraulically connected the sounds behind Onslow Beach and Topsail Island with sounds to the north and south of the region. In addition to the AIWW, a navigation channel measuring 90 feet wide at 10 feet below MLW was constructed from the AIWW through New River to the City of Jacksonville, NC in 1940. The authorization for the New River navigation project also included a 90-foot wide by 6-foot deep MLW channel through the ocean bar of New River Inlet to the AIWW via Cedar Bush Cut. Due to the limitations of dredging equipment capable of working in a shallow tidal inlet, maintenance of this seaward section of the authorized channel was not initiated until 1964.

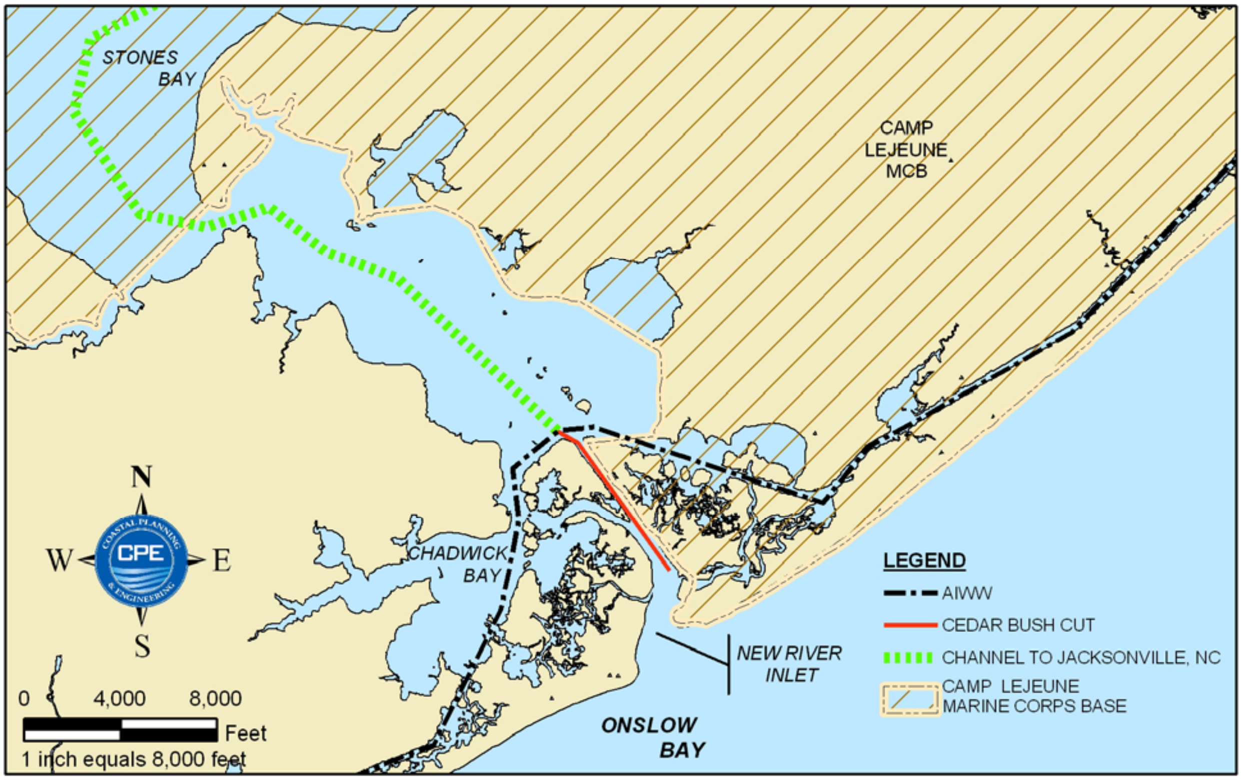


Figure 31. Navigation channels in the vicinity of New River Inlet.

New River Inlet Dredging History

In 1964, the Wilmington District Corps of Engineers commissioned the shallow draft sidecast dredge MERRITT to maintain the 90-foot wide, 6-foot deep channel across the inlet's ebb tide delta. The Wilmington District dredge fleet later expanded to include the FRY, a sidecast dredge similar to the MERRITT, and the small hopper dredge known as the CURRITUCK, all of which have worked intermittently in New River Inlet. The majority of the maintenance dredging has been performed by the sidecast dredges.

Dredging in New River Inlet begins in the inlet gorge, i.e., the deepest portion of the channel located between North Topsail Beach and Onslow Beach and extends across the ebb tide delta. No attempt is made to maintain a fixed channel alignment; rather the dredges follow the naturally deep channel that exists at the time of the maintenance operation. A summary of the dredging performed in New River Inlet is provided in Table 5 with a plot of the annual dredging volume shown in Figure 32. Also provided in Table 5 and indicated in Figure 32 are the average amounts of dredging performed in the inlet every 5 years (4 years for the 1999 to 2002 period).

Maintenance dredging in New River Inlet has generally increased since its inception in 1964 reaching a peak between 1996 and 2000 (Figure 32), a time period which corresponded to the occurrence of the moderate to severe tropical storms and hurricanes referred to previously. The dredging quantities given in Table 5 and plotted in Figure 32 are those reported by the Corps of

Engineers in its Annual Reports. In the case of sidecast dredges, the reported dredge volumes represent the volume of material that passed through the dredge pumps not the *in situ* volume actually removed from the channel. In this regard, sidecast dredges simply move material from the channel to a point immediately outside the channel by pumping the dredged material through a 90-foot long pipe which projects off to the side of the vessel. Since the authorized channel through New River Inlet is 90 feet wide, the sidecast dredges do not completely remove the material out of the channel with one passage as a certain percentage of the material flows back into the channel and is redredged during a subsequent passage of the dredge. Accordingly, the volume of material reportedly removed by the sidecast dredges is probably greater than the actual amount of *in situ* material removed. The volume of material removed by the CURRITUCK, which totals about 765,500 cubic yards since 1978, is deposited offshore of the adjacent beaches in water depths of 10 to 15 feet.

Table 5. New River Inlet dredging history.

Fisal Year	Name of Dredges	Volume Removed (cy)	5-year Average (cy)
1964	U.S. Merritt	29,620	
1965	U.S. Merritt	46,721	
1966	U.S. Merritt	30,441	
1967	U.S. Merritt	42,056	**1964 to 1968**
1968	U.S. Merritt	3,547	**30,477**
1969	U.S. Merritt	23,992	
1970	U.S. Merritt	42,579	
1971	U.S. Merritt	74,618	
1972	U.S. Merritt	80,956	**1969 to 1973**
1973	U.S. Merritt	65,680	**57,565**
1974	U.S. Merritt	48,370	
1975	U.S. Merritt	59,126	
1976	U.S. Merritt	142,928	
1977	U.S. Merritt	55,683	**1974 to 1978**
1978	U.S. Merritt, Currituck	186,869	**98,595**
1979	U.S. Merritt, Currituck	148,531	
1980	U.S. Merritt	120,977	
1981	U.S. Merritt	152,957	
1982	U.S. Merritt, Currituck	85,386	**1979 to 1983**
1983	U.S. Merritt	97,307	**121,032**
1984	U.S. Currituck	60,255	
1985	U.S. Merritt, Currituck	147,837	
1986	U.S. Merritt, Currituck, Fry	211,353	
1987	U.S. Merritt, Currituck, Fry	224,579	**1984 to 1988**
1988	U.S. Merritt, Fry	152,957	**159,396**
1989	U.S. Merritt, Fry	205,274	
1990	U.S. Merritt, Fry	267,720	
1991	U.S. Merritt, Fry	154,481	
1992	U.S. Merritt, Fry	238,399	**1989 to 1993**
1993	U.S. Merritt, Currituck, Fry	327,491	**238,673**
1994	U.S. Merritt, Fry	297,823	
1995	U.S. Merritt, Fry	236,966	
1996	U.S. Merritt, Currituck, Fry	419,426	
1997	U.S. Merritt, Currituck, Fry	585,093	
1998	U.S. Merritt, Fry	487,646	**1994 to 1998**
1999	U.S. Merritt, Fry	307,724	**405,391**
2000	U.S. Merritt, Fry	361,800	
2001	U.S. Merritt, Fry	331,700	
2002	U.S. Merritt, Fry	45,700	**1999 to 2002**
			261,731

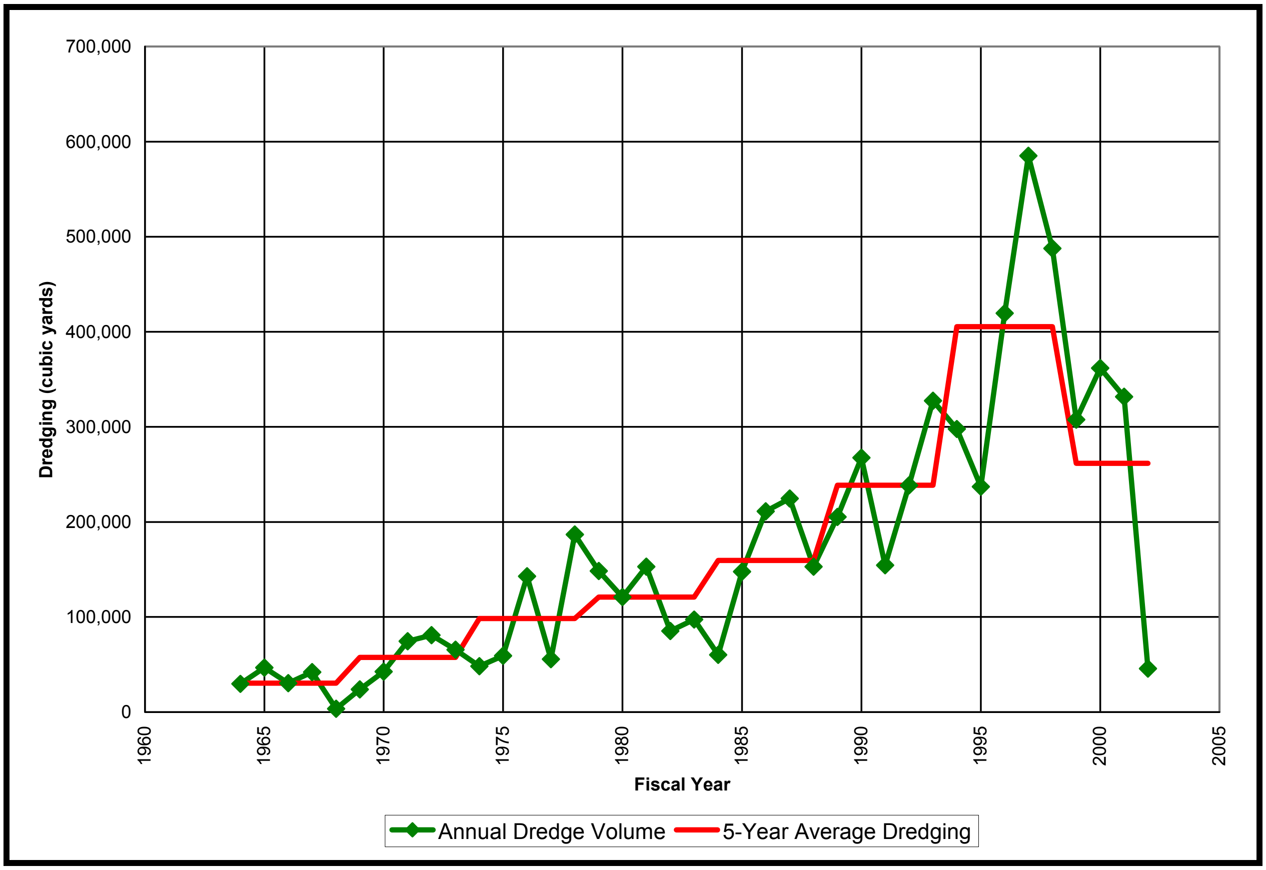


Figure 32. New River Inlet ocean bar channel dredging history.

While the past commitment by the Corps of Engineers to maintain the navigation channel in New River Inlet has been substantial, the effort rarely provides the authorized channel dimensions for any length of time. Also, current Administration priorities has reduced federal funding for shallow draft navigation channels which will make future maintenance of the New River Inlet channel uncertain.

Evaluation of New River Inlet Dredging

A detailed review of the dredging effort and its results was conducted over the period from March 2002 to July 2003, during which time the cumulative amount of material reportedly removed from the inlet channel by Corps of Engineers sidecast dredges totaled 427,000 cubic yards. This cumulative dredge volume was removed during 11 separate operations between July 2002 and July 2003. The Corps also conducted 11 condition surveys of the inlet channel between March 2002 and July 2003 from which the controlling depth in the channel was determined. The controlling depth is defined as the minimum depth in the marked navigation channel and is the depth that controls the draft of vessel able to use the channel.

Cumulative dredge quantities for the July 2002 to July 2003 time period are shown in Figure 33 along with the controlling depths indicated by the 11 condition surveys conducted between March 2002 and July 2003. During the approximate 16 month survey period, the controlling depth in the inlet channel never exceeded 4.8 feet MLW and reached a minimum controlling depth of 2.3 feet MLW in April 2003. This 16-month period, which is generally representative of the efforts by the Corps of Engineers and the results achieved, demonstrates that the present maintenance operations do not provide navigation interests with the channel dimensions needed to safely and efficiently navigate New River Inlet.

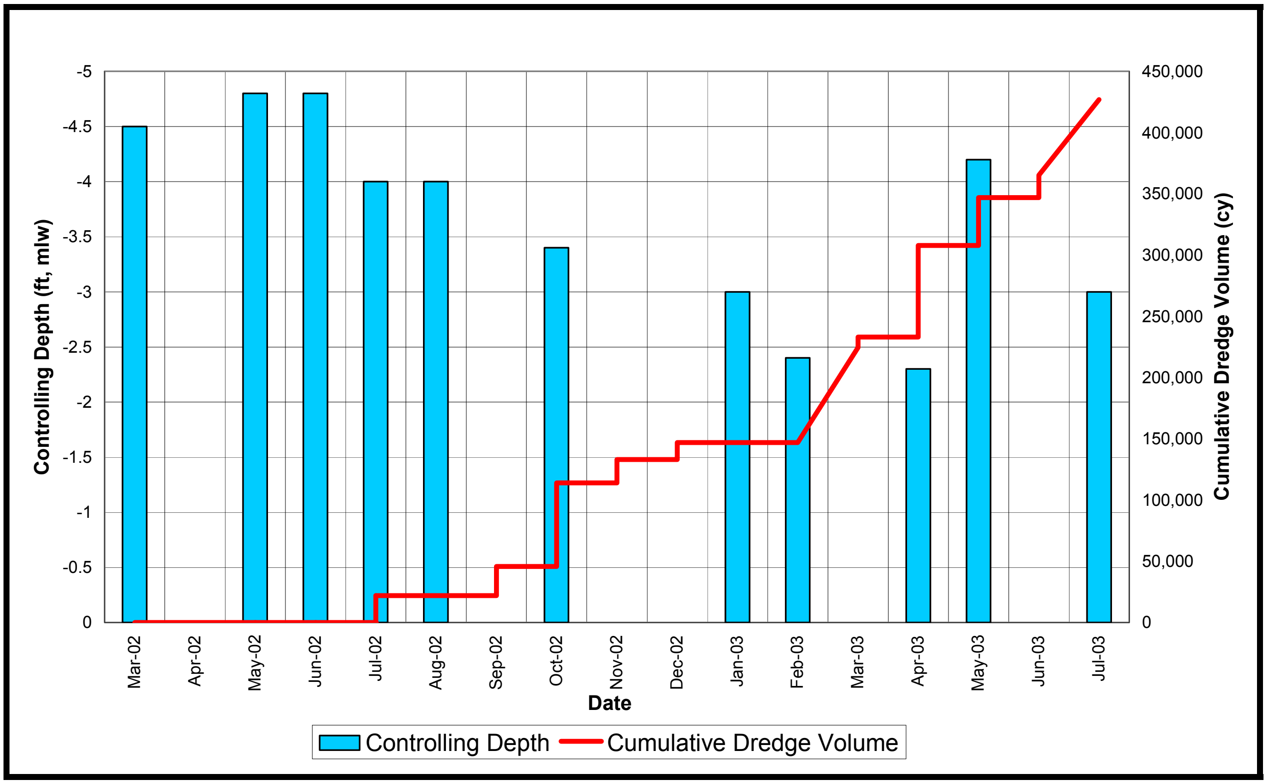


Figure 33. March 2002 to July 2003 cumulative dredge volumes and controlling depths.

Over the 10-year period from 1993 to 2002 inclusive, the Corps of Engineers costs for dredging the inlet channel averaged approximately $769,000 per year. Given the costs of the operation and the inability to provide the authorized channel dimensions, opportunities exist to improve the operation and benefit both navigation interests and the adjacent shoreline interests.

Maintenance Dredging in Cedar Bush Cut

Dredging in Cedar Bush Cut (Figure 31), the channel connecting the AIWW with New River Inlet; was initiated in 1976 with the removal of 730,600 cubic yards. Subsequent maintenance of the connecting channel was performed in 1978, 1988, 1997, and every year between 2000 and 2002. The dredging in Cedar Bush Cut is performed by hydraulic pipeline dredges with disposal of the dredged material on the north end of North Topsail Beach. A summary of the dredging in Cedar Bush Cut is provided in Table 6. Over the 10-year period 1993 to 2002 inclusive, the costs for maintaining Cedar Bush Cut averaged over $133,000 per year. Thus the total cost of maintaining the New River Inlet ocean bar channel and the connecting channel through Cedar Bush Cut has averaged over $900,000 per year during the 10-year period from 1993 to 2002.

Table 6. Cedar Bush Cut dredging history.

Fiscal Year	Dredge(s)	Volume Removed (cy)
1976	Marion	730,600
1978	Marion, Northwood II, Richmond	747,300
1988	Arlington	124,900
1997	Marion and Richmond	92,000
2000	Richmond	15,800
2001	Blue Ridge	17,500
2002	Marion	154,200

Impact of Channel Dredging on New River Inlet Tidal Prism

The improved hydraulic connections between the sounds, New River, and New River Inlet resulting from the various navigation projects, particularly the construction of the AIWW, appeared to substantially increase the tidal prism of New River Inlet. The increase in the size of the ebb tide delta between May 1938 (shortly after the construction of the AIWW) and May 1958 is evident on Figure 34. The size of an inlet's ebb tide delta is a function of its tidal prism according to the following relationship developed by Walton and Adams (presented in Dean and Dalrymple, 2002):

$$V = 10.7 \times 10^{-5} T_p^{1.23}$$

where: V = volume of material in the ebb tide delta (cubic yards),
T_p = tidal prism in cubic feet.

A Planning Assistance Report (PAR) prepared for the Town of North Topsail Beach by Tom Jarrett Coastal Engineering (Jarrett, 2002) found that the surface area of the New River Inlet ebb tide delta increased from 1.63 million square feet in 1938 to 9.53 million square feet in 1958. For comparative purposes, the total vertical height of the delta from its surface to its depth of closure with the normal beach profile was assumed to be 25 feet resulting in ebb tide delta volumes of 1.5 million cubic yards and 8.8 million cubic yards for 1938 and 1958, respectively. Substitution of these estimated bar volumes into the above relationship implied tidal prisms of 1.8×10^8 cubic feet for the 1938 inlet condition and 7.5×10^8 cubic feet for 1958. Thus, based on the increase in size of the ebb tide delta, the tidal prism of New River Inlet appeared to increase by a factor of 4 between 1938 and 1958.

While the increase in tidal flow through the inlet resulted in a larger ebb tide delta, the PAR concluded that the improved flow conditions resulted in a more stable inlet in terms of its coastwise position, i.e., the increased flow regime reduced inlet migration to the north and to the south. The repetitive dredging of the inlet ebb tide delta channel since 1964 was identified as having altered the planform shape of the delta resulting in a more seaward protrusion of the delta

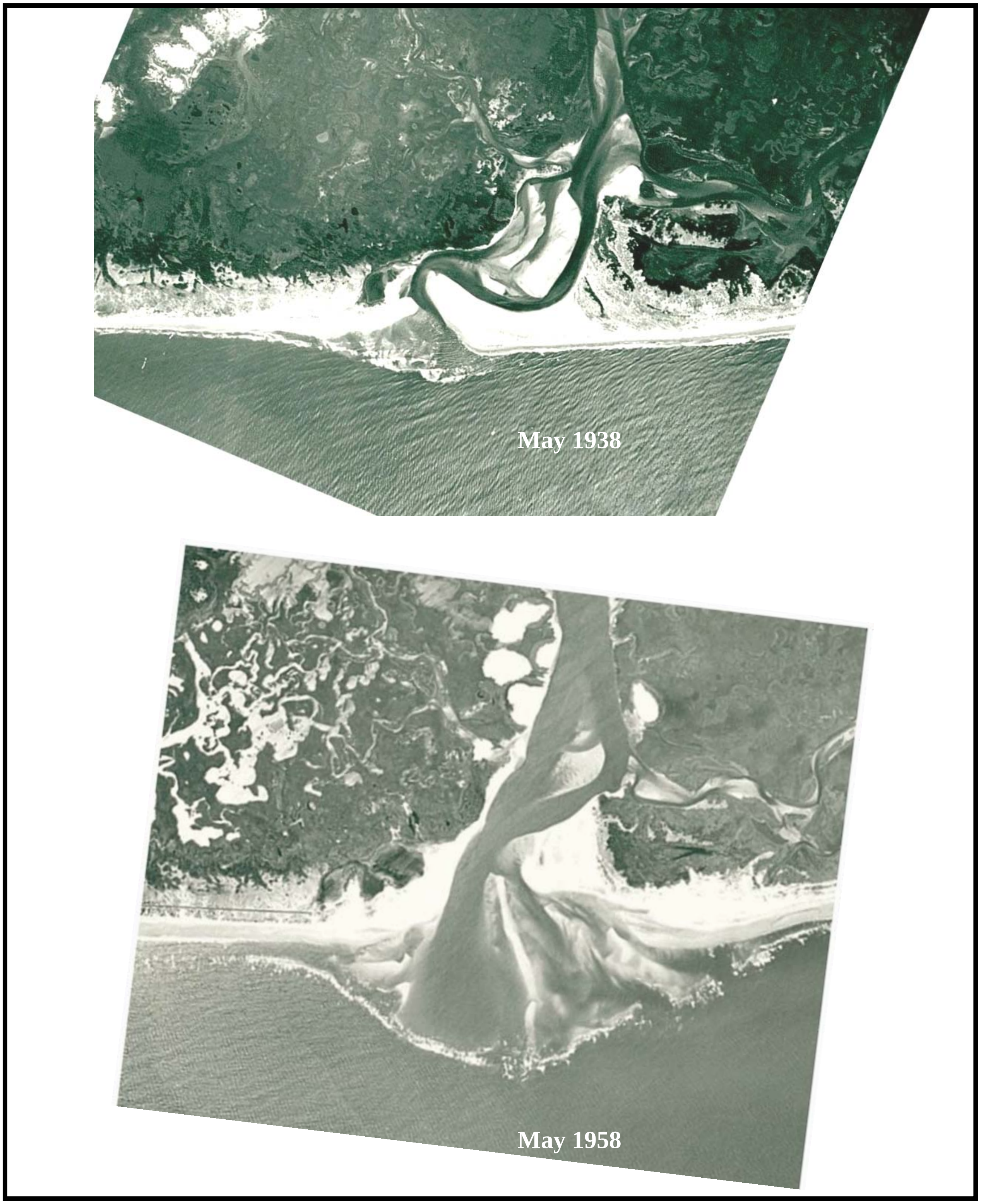


Figure 34. May 1938 and May 1958 aerial photos of New River Inlet.

relative to the adjacent shorelines. Finally, the PAR found significant relationships between the orientation of the bar channel and the behavior of the adjacent shorelines.

Geomorphic Analysis of New River Inlet

The PAR results discussed above were based on comparisons of uncontrolled sets of aerial photographs covering the period from 1938 to 2001. In order to obtain more definitive results regarding the behavior of New River Inlet and its impacts on the adjacent shorelines, CPE-NC subcontracted with Dr. William J. Cleary of the University of North Carolina at Wilmington (UNCW) to conduct a detailed geomorphic analysis of New River Inlet. The primary focus of the geomorphic analysis was the movement and deflection of the inlet's ebb or ocean bar channel and its influence on the ocean shoreline change patterns along the North Topsail Beach and Onslow Beach. In addition to changes in the ocean bar channel, the geomorphic analysis included measurements of: changes in the width of the inlet, movement of the inlet shorelines, surface area of the ebb tide delta, and changes in the shoreline positions on the northeast end of North Topsail Beach and the southwest end of Onslow Beach.

Methodology

Changes in New River Inlet and the adjacent ocean shorelines of North Topsail Beach and Onslow Beach were determined through an analysis of representative aerial photographs taken between March 1962 and March 2003. Seventeen (17) sets of aerial photographs were obtained from the Wilmington District Corps of Engineers aerial photograph archives, scanned, and orthorectified to removed horizontal distortions. All rectified photographs were referenced to the North Carolina State Plane Coordinate System (NAD '83 datum) by using ground control points from the 1998 NC Division of Coastal Management digital orthophotos. The digitized aerial photographs were entered into a GIS database for comparison.

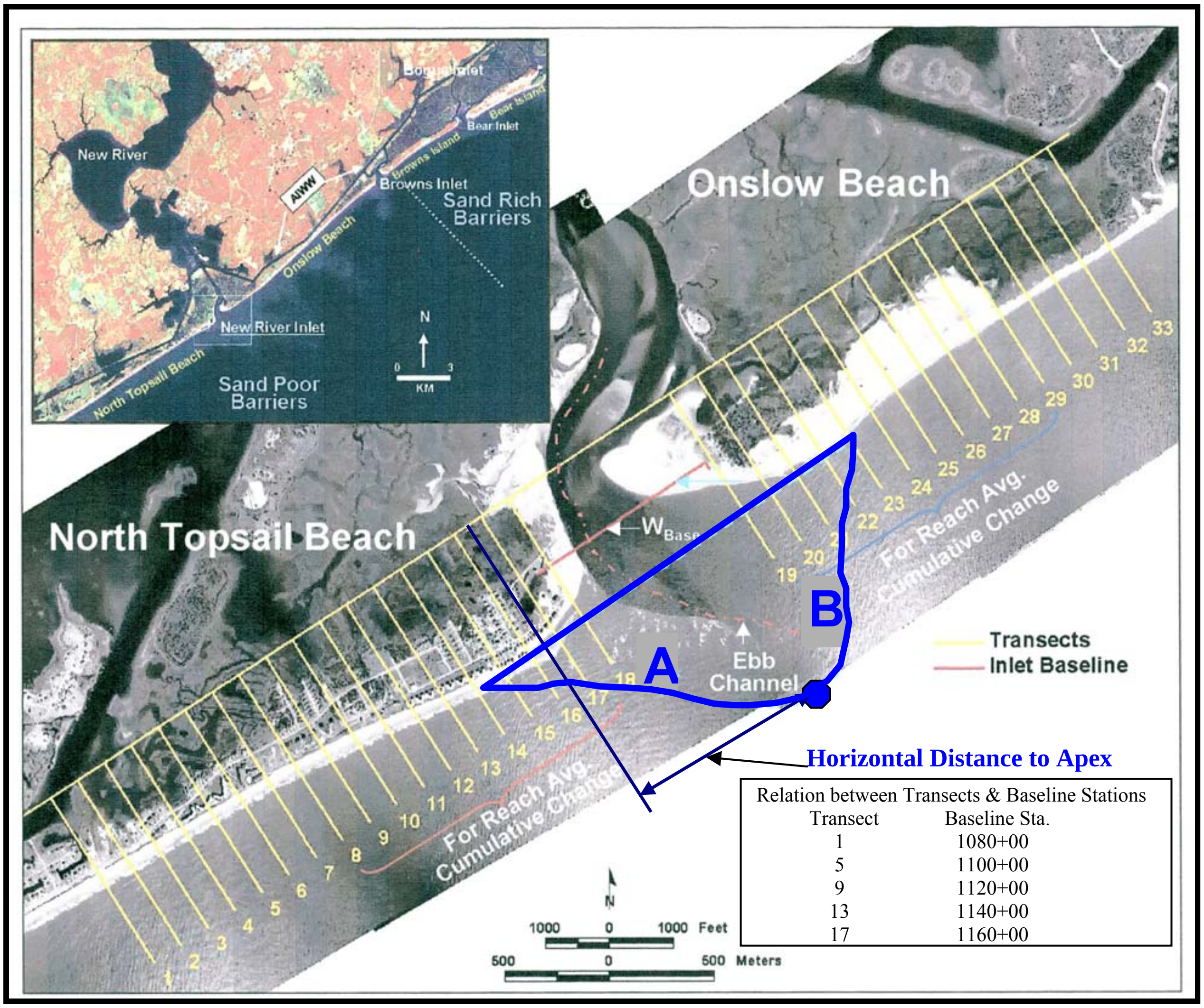
Objective

The overall objective of the geomorphic analysis was to develop information on changes in the configuration of New River Inlet, particularly the ocean bar or ebb tide delta, and to see if the changes in the inlet could be correlated to changes in the adjacent shorelines on North Topsail Beach and Onslow Beach. Ocean bar features evaluated include the orientation of the ocean bar channel, offshore position of the apex (seaward most protrusion) of the ebb tide delta (ocean bar), as defined by the breaker line on the aerial photos, the alongshore position of the apex, the surface area of the ebb tide delta, and the surface area of the delta located southwest and northeast of the main bar channel. The inlet analysis also tracked changes in the inlet shorelines on North Topsail Beach and Onslow Beach and migratory tendencies of the inlet.

Shore Transects and Reference Points

Changes in the position of the adjacent ocean shorelines were measured along 33 transects spaced at 500-foot intervals shown in Figure 35. The position of the transects relative to the USACE baseline is given in Figure 35. An inlet baseline, shown in red in Figure 35, was used to measure changes in the position of the ebb channel midpoint, inlet width, changes in the inlet shoulders associated with the migration of the ebb channel, and as a point of reference in determining the offshore distance to the apex of the ebb tide delta. The apex of the ebb tide delta in Figure 35 is indicated by the blue octagon. A third reference line located midway between transects 16 and 17 (baseline station 1157+50), shown in blue in Figure 35, was used to determine the relative horizontal or alongshore position of the delta apex. The azimuth of the ocean bar channel (i.e., angle measured from grid north) was determined from the point where the channel midpoint intersected the inlet baseline and the point where the channel crossed the zone of breaking waves.

The relative surface area of the ebb tide delta measured on each set of aerial photographs was identified by the zone of breaking waves around the seaward periphery indicated by the solid line in Figure 35. The portions of the ebb tide delta located southwest of the main channel and northeast of the main channel are designated as “A” and “B” in Figure 35, respectively.



Relation between Transects & Baseline Stations	
Transect	Baseline Sta.
1	1080+00
5	1100+00
9	1120+00
13	1140+00
17	1160+00

Figure 35. Transects, inlet baseline, and reference points used to determine ocean and inlet shoreline changes.

Morphological Phases of New River Inlet

While the main focus of the detailed geomorphic analysis covered the period from March 1962 to March 2003, Dr. Cleary identified four distinct phases in the evolution of New River Inlet since 1938. The first phase covered the period from 1938 to 1945 during which time the inlet was adjusting to the new hydrodynamic conditions associated with the construction of the AIWW and the channel connecting the AIWW with the City of Jacksonville. During this initial phase, the ebb tide delta began to enlarge and the inlet throat migrated to the southwest toward North Topsail Beach. The bar channel was also significantly skewed toward North Topsail Beach.

The second stage of inlet evolution covered the period from 1945 to approximately 1962. During this phase, the inlet assumed morphologic features recognized today including an enlarged ebb tide delta and extensive marginal flood channel on the northeast or Onslow Beach side of the inlet. The growth of the ebb tide delta stabilized by the mid-1950's, but continued to fluctuate in size around a mean area of 10.6 million square feet in response to varying climatic conditions, particularly the impact of tropical storms and nor'easters. During most of this period, the ocean bar channel was oriented either perpendicular to the adjacent shorelines or skewed slightly toward North Topsail Beach.

The third phase covers the period from 1962 to 1988 during which repetitive maintenance dredging of the ebb channel (channel dredging began in 1964) appeared to cause the apex of the delta to extend farther seaward. During this third phase of inlet evolution, the apex of the delta was offset to the southwest or off North Topsail Beach. These changes resulted in an asymmetric shape of the ebb tide delta in which most of the surface area of the delta was located on the northeast or Onslow Beach side of the bar channel.

The fourth and final phase of the inlet evolution covers the period from 1988 to the present during which time the bar channel has been oriented to the southeast or toward Onslow Beach. More detailed discussions of the changes observed in New River Inlet and the adjacent shorelines over the last two periods are provided below.

Ocean Shoreline Changes Adjacent to New River Inlet

Changes measured in the shoreline positions of North Topsail Beach and Onslow Beach are discussed first since the primary focus of the geomorphic analysis is to relate changes in the inlet to changes on the adjacent shorelines. The historic changes of the shorelines provides a time table of significant behavioral changes of the shoreline, which flags timeframes to look for changes in New River Inlet.

Total Shoreline Changes. A graph depicting the total change in the shoreline positions on North Topsail Beach and Onslow Beach between March 1962 and March 2003 is provided in Figure 36. For the entire 41 year period, the section of North Topsail Beach between transects 7 and 15 (baseline stations 1110+00 to 1150+00) experienced net accretion. This particular area of North Topsail Beach extends from just north of Topsail Dunes to Topsail Reefs. Large losses in the shoreline position were observed along transects 16 to 18 (baseline stations 1155+00 to 1165+00), however, these three transects are technically located within the confines of the ebb tide delta of New River Inlet and therefore tend to respond more quickly to changes in New River Inlet. Given the recent erosion problems in the vicinity of Topsail Reefs, the total record of shoreline change does not capture recent trends. On Onslow Beach, the greatest recession of the shoreline occurred between transects 19 to 21, which are also technically located within the confines of the ebb tide delta of New River Inlet. The remainder of Onslow Beach included in this shoreline analysis experienced similar total shoreline recessions ranging from approximately 400 feet to 500 feet between March 1962 and March 2003.

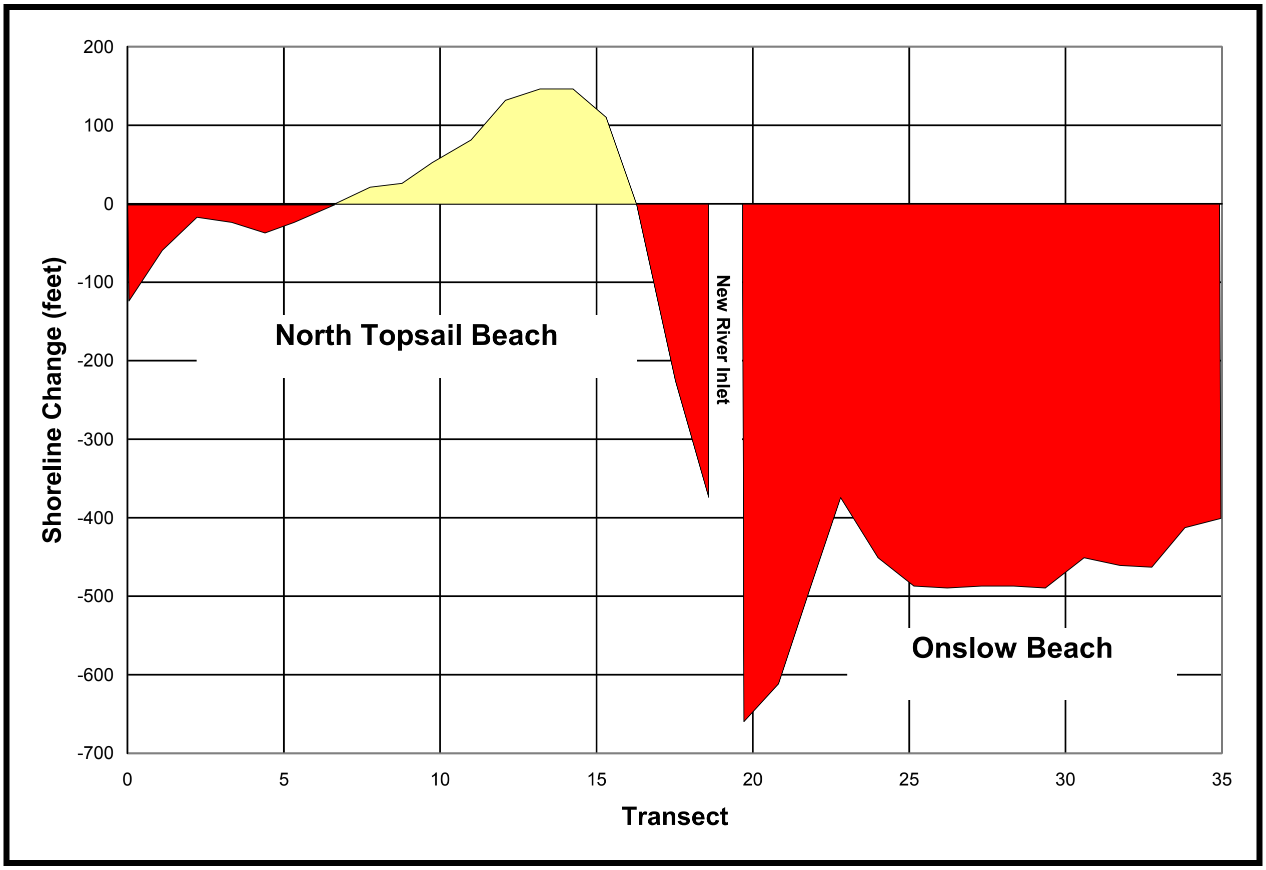


Figure 36. Total shoreline change 1962 to 2003, northeast end of North Topsail Beach and southwest end of Onslow Beach.

Temporal Shoreline Changes – North Topsail Beach. Cumulative changes in the shoreline position on North Topsail Beach between March 1962 and March 2003, averaged over transects 1 to 15 (baseline stations 1080+00 to 1150+00), are shown in Figure 37 along with cumulative changes for transects 1 to 7 (1080+00 to 1110+00) and transects 8 to 15 (1115+00 to 1150+00). Transects 16 to 18 are not included in these average cumulative changes since, as mentioned above, these three transects are located within the confines of the ebb tide delta of New River Inlet.

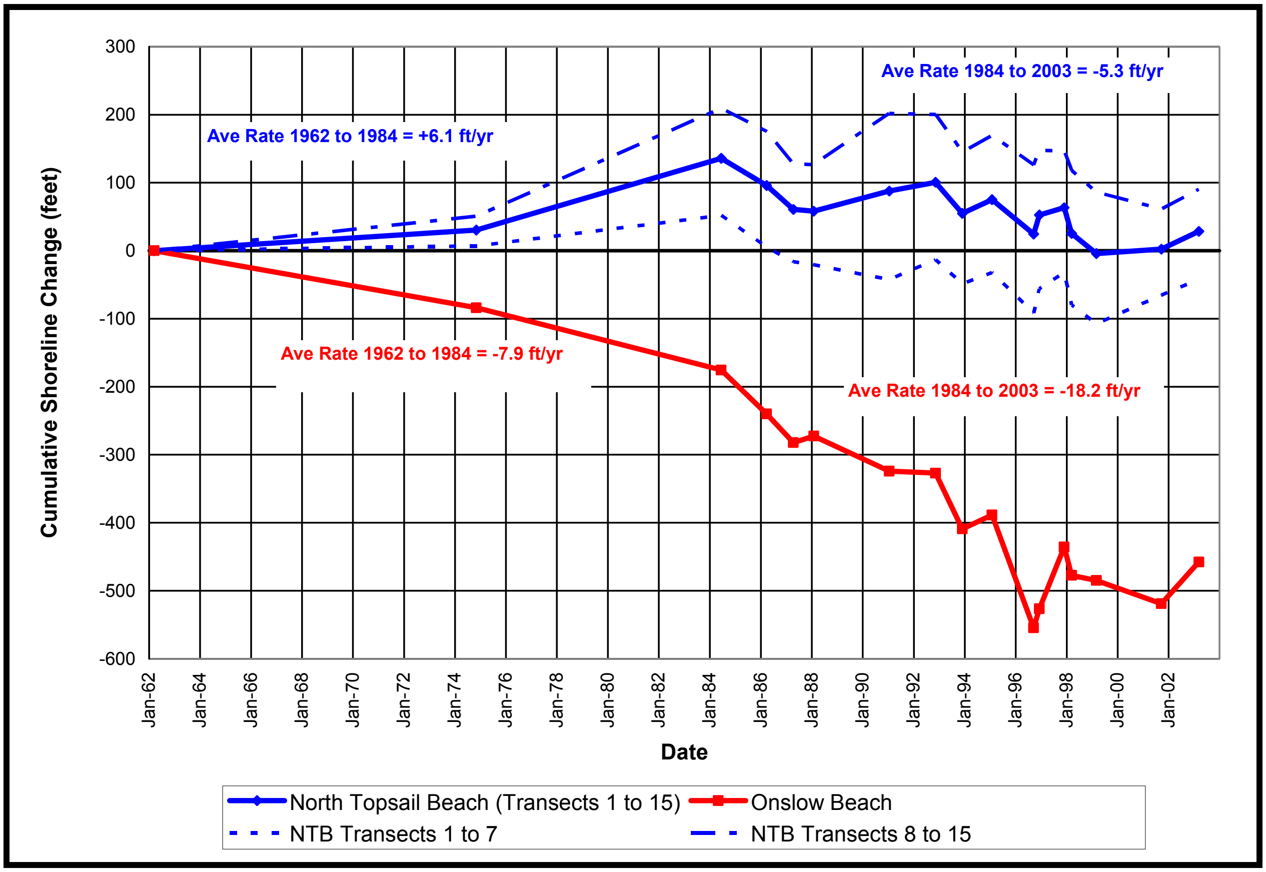


Figure 37. Cumulative shoreline changes North Topsail Beach transects 1 to 15 (baseline stations 1080+00 to 1150+00) and Onslow Beach (transects 22 to 33), March 1962 to March 2003.

Between March 1962 and June 1984, the north end of North Topsail Beach, represented by transects 1 to 15 (baseline stations 1080+00 to 1150+00), advanced at an average rate of 6.1 feet/year. An accretionary trend was observed for transects 1 to 7 (1080+00 to 1110+00) and 8 to 15 (1115+00 to 1150+00), however, the advance between transects 1 to 7 was somewhat less than that which occurred between transects 8 to 15. After June 1984 and continuing for the remainder of the analysis period, the overall response on the north end of North Topsail Beach has been recession with the rate for transects 1 to 15 averaging -5.3 feet/year. During this latter period, there was no significant difference in the spatial behavior of the shoreline on the north end of North Topsail Beach as transects 1 to 7 and transects 8 to 15 both receded at essentially the same rate, i.e., average rate of -5.3 feet/year. The similar erosion trends for transects 1 to 7 and 8 to 15 between June 1984 and March 2003 demonstrates that the total shoreline changes between March 1962 and March 2003 provided in Figure 36 do not represent the contemporary behavior of this section of the shoreline on North Topsail Beach because the entire north end of the island has been receding at a rate of 5.3 feet/year since 1984.

Temporal Shoreline Changes – Onslow Beach. Cumulative shoreline changes averaged over transects 22 to 33 on Onslow Beach are also shown in Figure 37. These average rates do not include transects 19 to 21 since they are within the confines of the New River Inlet ebb tide delta. Shoreline recession on Onslow Beach has been pervasive for the entire 41 year period; however, the behavior of the shoreline appeared to change around June 1984 when the rate of shoreline recession increased from -7.9 feet/year observed between March 1962 and June 1984 to -18.2 feet/year for the June 1984 to March 2003 time period.

The shorelines on both the northeast end of North Topsail Beach and the southwest end of Onslow Beach began to respond differently than in the past sometime around the middle 1980's. This is about the same time that the shoreline behavior on Bear Island (Hammocks Beach State Park) and the west end of Emerald Isle, which are located adjacent to Bogue Inlet, began to behave in a manner different from the past (CPE, 2004). The shoreline responses on Bear Island and Emerald Isle were related to changes in Bogue Inlet, primarily the eastward migration of the main inlet channel. Both New River Inlet and Bogue Inlet respond to the same climatic factors such as waves, winds, and coastal storms. Therefore, changes in New River Inlet that may have occurred around the mid 1980's could be the cause of the observed shoreline responses on North Topsail Beach and Onslow Beach.

Changes in New River Inlet

Observed changes in New River Inlet developed by Dr. Cleary, are presented below with an emphasis on relating the observed inlet changes to changes on the adjacent shoreline. The aerial photographs used in the analysis are shown in Figures 38 to 41. The inlet changes summarized in the following sections include: (a) inlet shorelines on North Topsail Beach and Onslow Beach; (b) movement of the channel midpoint; (c) orientation of the main ebb channel; (d) offshore distance to the apex of the ebb tide delta; (e) alongshore distance to the apex of the ebb tide delta; and (f) surface area of the ebb tide delta.

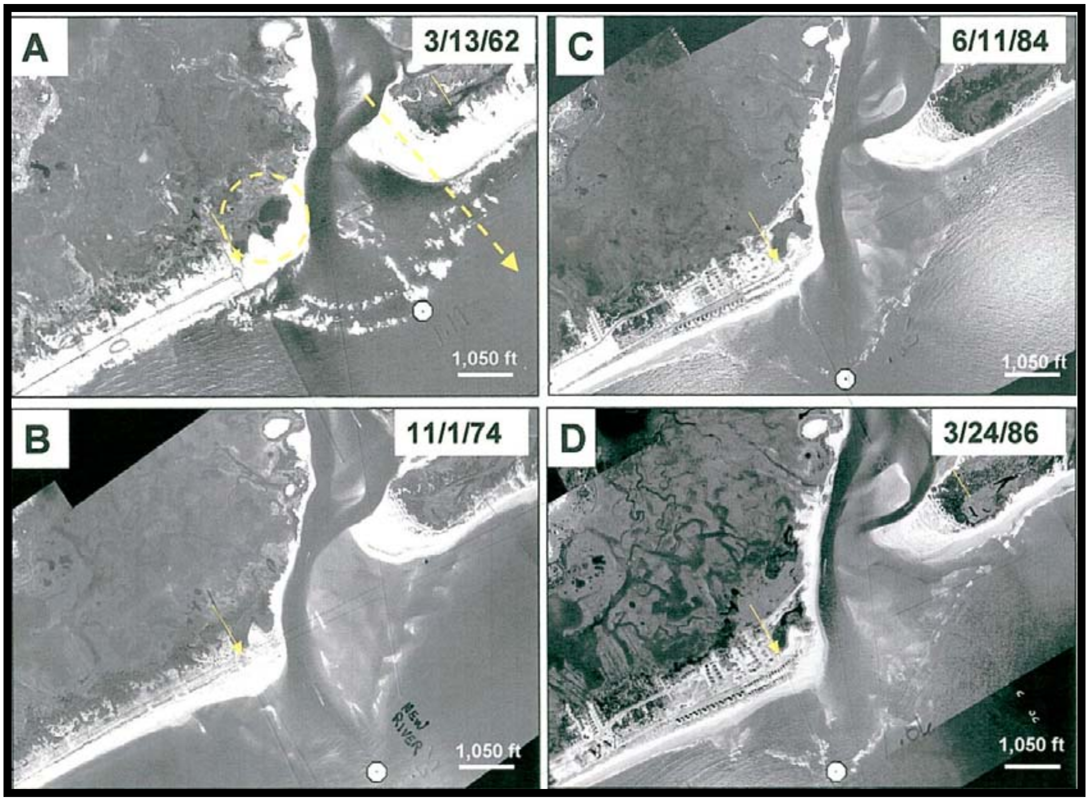


Figure 38. New River Inlet aerial photos (March 1962 to March 1986).

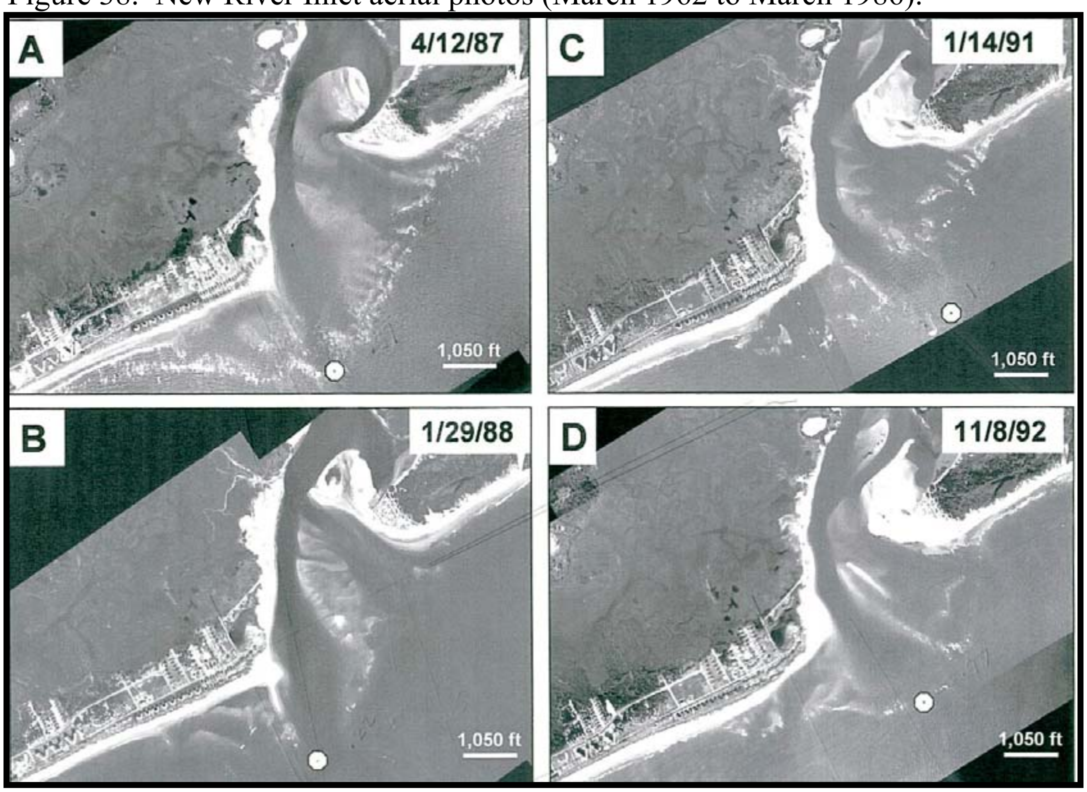


Figure 39. New River Inlet aerial photos (April 1987 to November 1992).

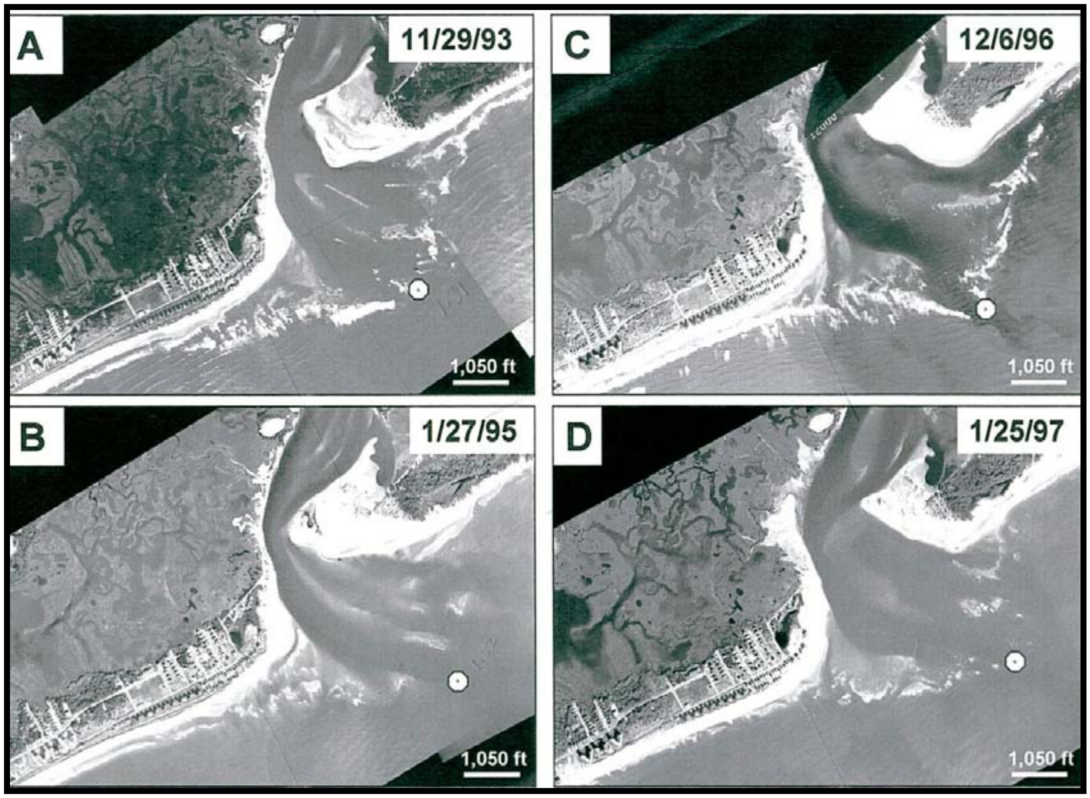


Figure 40. New River Inlet aerial photos (November 1993 to January 1997).

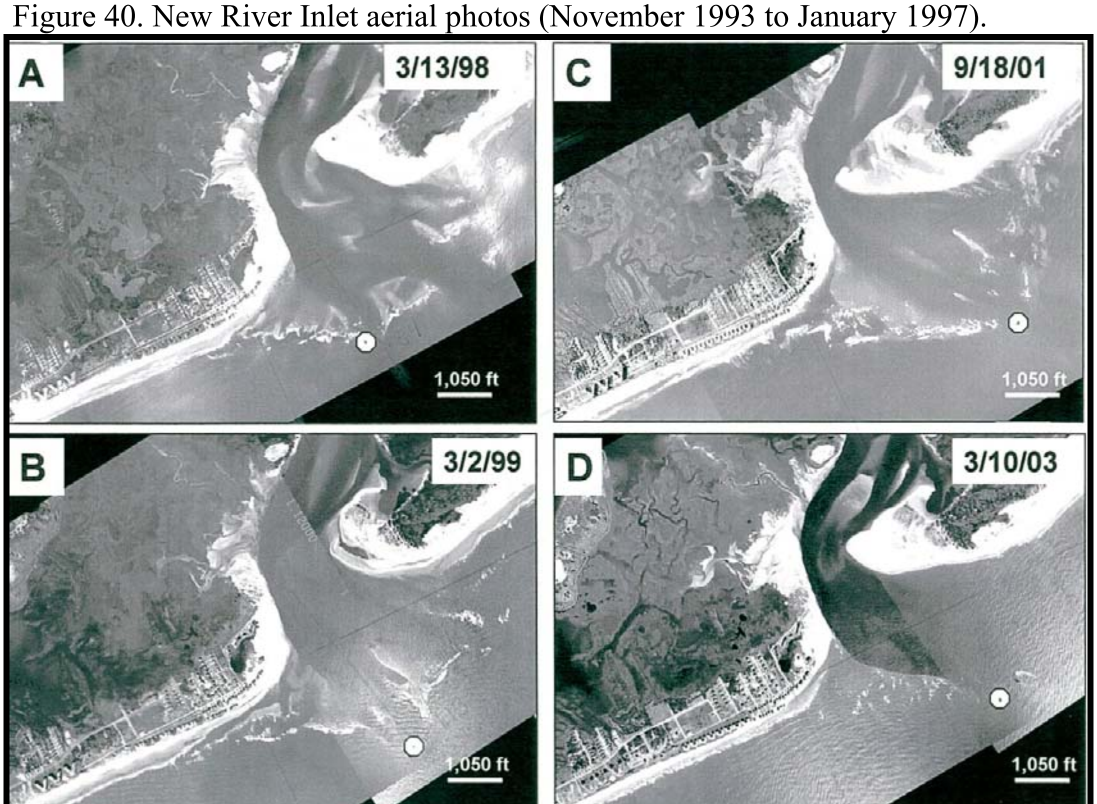


Figure 41. New River Inlet aerial photos (March 1998 to March 2003).

Inlet Shoreline Changes

The position of the inlet shorelines on North Topsail Beach and Onslow Beach were recorded at the point where the inlet baseline intersected the shorelines. A plot of the cumulative change in the two shorelines is provided in Figure 42.

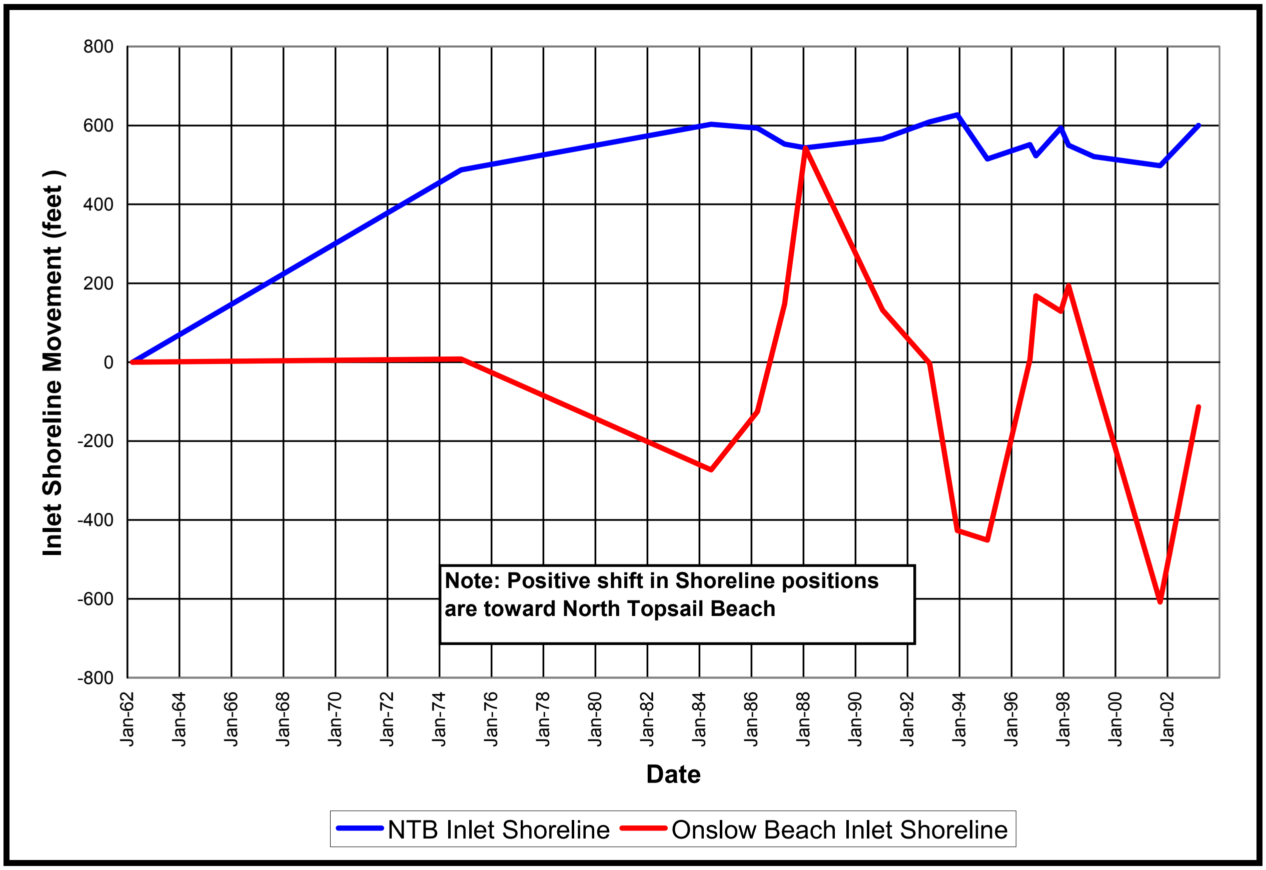


Figure 42. Cumulative movement of the New River Inlet shorelines measured along the inlet baseline between March 1962 and March 2003.

The North Topsail Beach inlet shoreline receded approximately 600 feet (moved southward) between 1962 and 1984 but has been stable since 1984. Inlet shoreline changes on Onslow Beach are more erratic, experiencing cycles of northward (erosion) and southward movement. Dr. Cleary associated this erratic behavior to periodic influxes of littoral sediment that migrate into the inlet from the northeast side of the ebb tide delta and are subsequently transported into the inlet throat as a recurved sand spit. The spit continues to grow in a southward direction for some period of time until it is cut back or eroded by tidal currents and possibly increased wave activity.

Aerial photographs used in the analysis captured two sand spit growth and erosion cycles, one between June 1984 and November 1993 and the other between November 1993 and September 2001 (Figures 38 to 41). During the 1984 to 1993 sequence, a large shoal had formed just north of the south tip of the distal end of Onslow Beach and eventually merged with the south tip of Onslow Beach. The merger of the shoal with the south tip of Onslow Beach accounted for the rapid movement of the Onslow Beach inlet shoreline between 1984 and 1988 depicted in Figures 38 and 39. The Onslow Beach inlet shoreline eroded between 1988 and 1993 at which time a new accretionary cycle began. This latest cycle appeared to end around September 2001.

Channel Midpoint

The cumulative movement of the New River Inlet channel midpoint, located at the point where the channel crosses the inlet baseline, is shown in Figure 43 and appears to follow the same general trend as the North Topsail Beach inlet shoreline. Between March 1962 and June 1984, the channel migrated approximately 680 feet to the south, which represents an annual average rate of 30.5 feet/year. The midpoint of the channel has continued to slowly migrate to the south since 1984 with the average rate of southward migration equal to 6.2 feet/year. The southward tendency of the channel since 1984 has not been reflected in inlet shoreline changes on North Topsail Beach as a result of the general widening of the inlet due to net erosion of the Onslow Beach inlet shoreline (Figure 42).

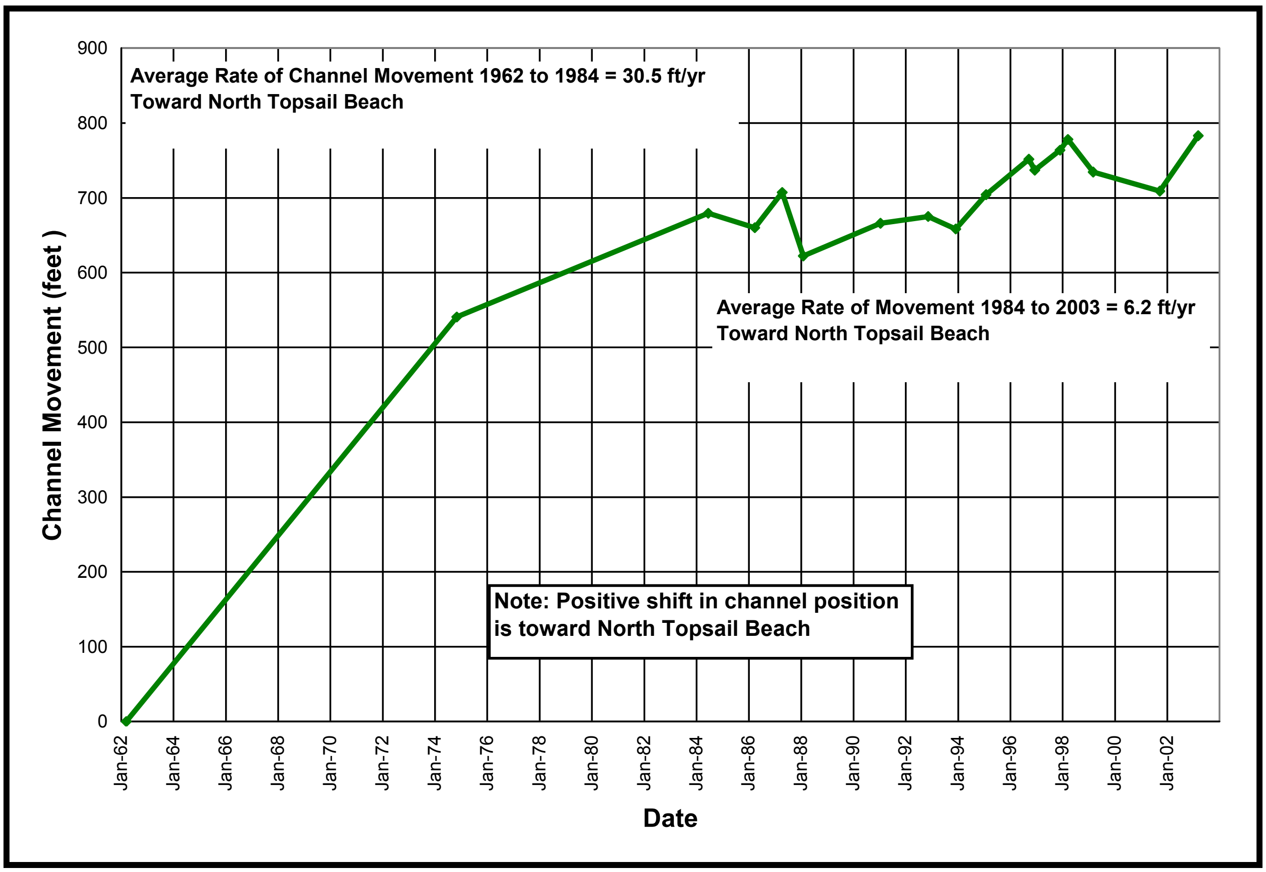


Figure 43. Cumulative movement of New River Inlet channel midpoint measured along the inlet baseline (March 1962 to March 2003).

Effect of Channel Orientation on Adjacent Beaches

The orientation of the main ebb channel of an inlet normally plays a significant role in dictating the behavior of the adjacent shorelines. When the channel is oriented toward a particular beach, say the downdrift beach (North Topsail Beach in this case), that shoreline normally experiences advance. The accretion is associated with two primary phenomena; namely, the wave sheltering provided by the ebb tide delta downdrift of the channel and the refraction of waves around the ebb tide delta. The first phenomenon is rather obvious. With regard to wave refraction, the curvature of the ebb tide delta acts as a focusing lens which caused the wave crest to change direction as they pass over the delta resulting in wave crest moving in the direction of the inlet regardless of the offshore direction. The point where the wave direction changes due to wave refraction is referred to as a nodal zone. An example of waves refracting over the ebb tide delta of New River Inlet is shown in Figure 44.

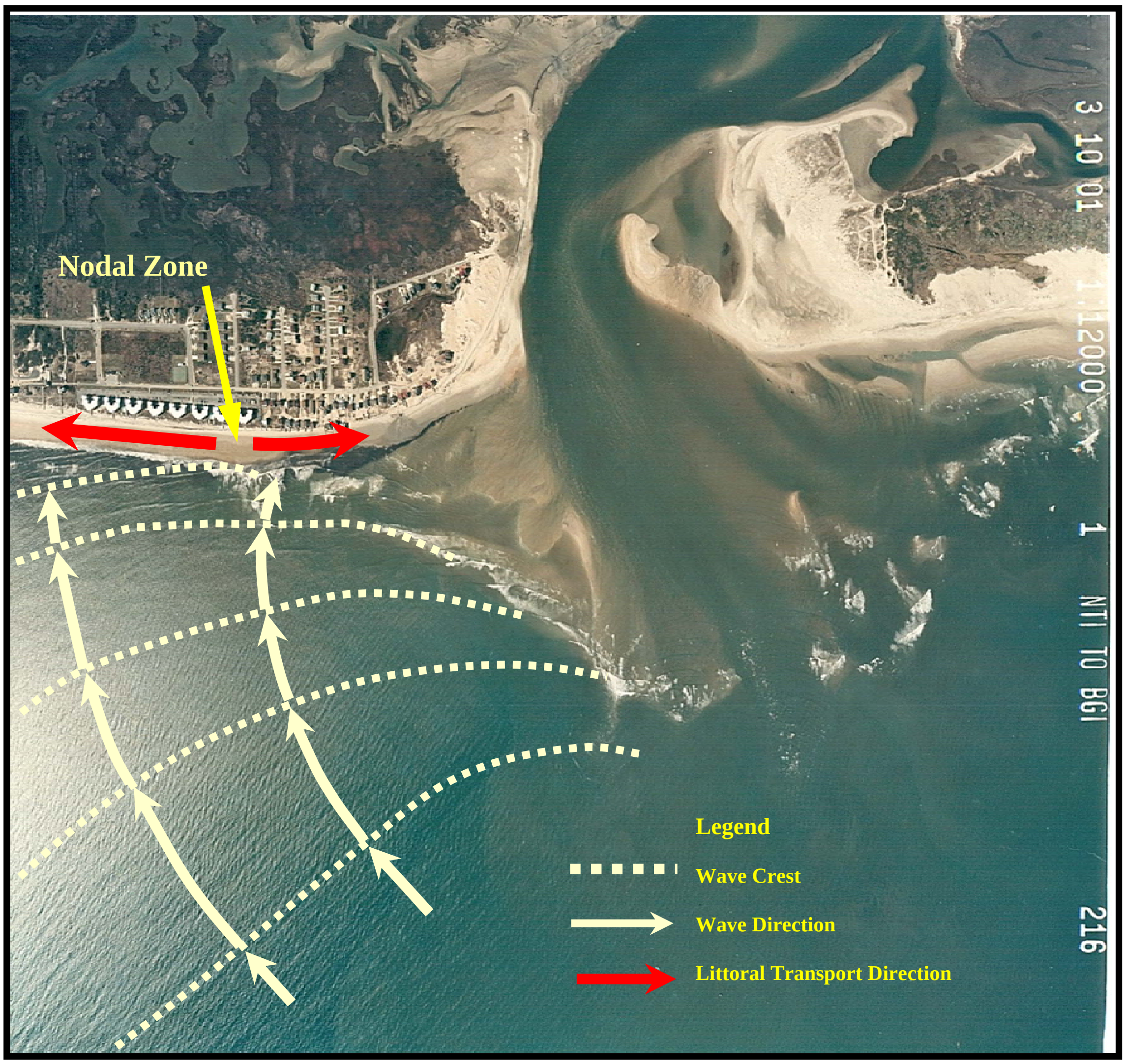


Figure 44. Example of wave refraction showing change in wave direction and sediment transport as waves propagate over the ebb tide delta of New River Inlet.

The photo shown in Figure 44 was taken in March 2001 by the Corps of Engineers during which time waves were approaching the inlet from the southeast direction that would normally tend to move littoral sediment to the southwest. However, as the waves pass over the ebb tide delta, the direction of the waves (indicated by the arrows) changes with the wave direction near the inlet moving toward the channel. Downdrift of the inlet, the waves continue to strike the shoreline at an angle that would drive sediment toward the southwest. The area where sediment transport diverges is designated as the nodal zone in Figure 44. The wave refraction phenomenon just described was responsible for the shoreline bulge south of New River Inlet as discussed previously.

The orientation or azimuth (degrees from north) of the main inlet channel was determined from each set of aerial photographs from the inlet baseline to where the channel crossed the zone of breaking waves. The azimuth of the channel was compared to the azimuth of a line oriented perpendicular to the general alignment of the adjacent shorelines with a plot of the deviation of the channel orientation from this normal azimuth shown in Figure 45. As a matter of reference, the normal azimuth is oriented at 150°. Positive deviation angles in Figure 45 indicate that the general alignment of the bar channel was toward North Topsail Beach.

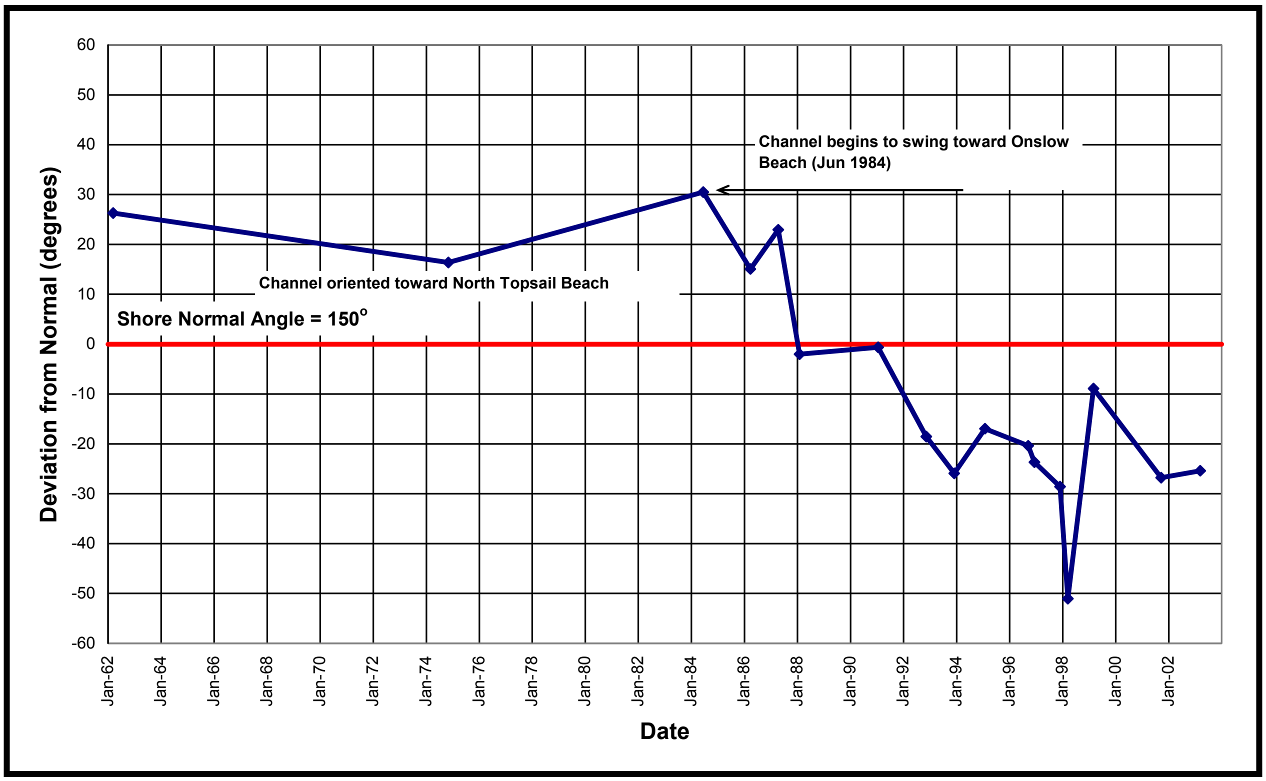


Figure 45. Deviation of New River Inlet ocean bar channel alignment from normal.

The ocean bar channel was oriented toward North Topsail Beach between 1962 to around January 1988 but began to reorient itself toward Onslow Beach in June 1984 (Figure 45). The shoreline along North Topsail Beach started to change from an accretional signature to an erosional signature at this time (1984). The southeastward deflection of the channel peaked in

March 1998; however the channel naturally reoriented to a more perpendicular alignment in that same month. After this natural reorientation, the channel began to swing back toward Onslow Beach.

During times in which the channel was oriented toward North Topsail Beach, a distinct linear shoal formed parallel to the channel off the north end of North Topsail Beach. This linear shoal feature is evident on the 1986 to 1988 aerial photos (Figures 38 and 39) with the shoal appearing to be above water on the January 1988 photo. The presence of the linear shoal indicates that there was an absence of marginal flood channels off the north end of North Topsail Beach during this time. As the channel moved toward Onslow Beach, the linear shoal disappeared and marginal flood channels began to appear parallel to the shoreline off the north end of North Topsail Beach. The movement of the bar channel toward Onslow Beach not only exposed the north end of North Topsail Beach to greater wave energy and moved the nodal zone farther north, the reorientation of the channel also allowed tidal currents in the marginal flood channel to transport material into the inlet. The combined effect has contributed to the gradual erosion of the shoreline bulge that has been a prominent feature of North Topsail Beach since the early 1970's. The material eroded from the ocean shoreline migrated around the North Topsail Beach inlet shoreline and contributed to the stability of the inlet shoreline observed since 1984.

Offshore Distance to Apex of Ebb Tide Delta

A plot of the distance from the inlet baseline to the apex of the ebb tide delta between 1962 and 2003 is provided in Figure 46. The offshore distance to the apex increased approximately 700 feet between 1962 and 1974. This increase in offshore distance corresponded to the time when the Corps of Engineers began to routinely maintain the channel using sidecast dredges. Dr. Cleary surmised that the repetitive dredging gradually increased the length of the bar channel in a manner similar to that observed at Beaufort Inlet (USACE, 1976) and the Cape Fear River Entrance (USACE, 1991). However, as shown in Figure 46, the offshore distance decreased from 1974 to around 1995 and then began to move farther offshore between 1995 and 2003. As noted above, the southeasterly deflection of the channel peaked in March 1998, however, the March 1998 photo shows the existence of two ebb channels, one oriented along a 99^{o} azimuth and the other approximately 143^{o}. On the March 1998 photo, the apex of the delta was located closer to the 143^{o} channel. Except for March 1988, the offshore distance to the apex of the ebb tide delta generally corresponds to changes in the orientation of the ebb tide delta. In this regard, when the channel is oriented toward Onslow Beach, the offshore distance to apex is at a minimum and increases as the channel reorients toward a more perpendicular alignment.

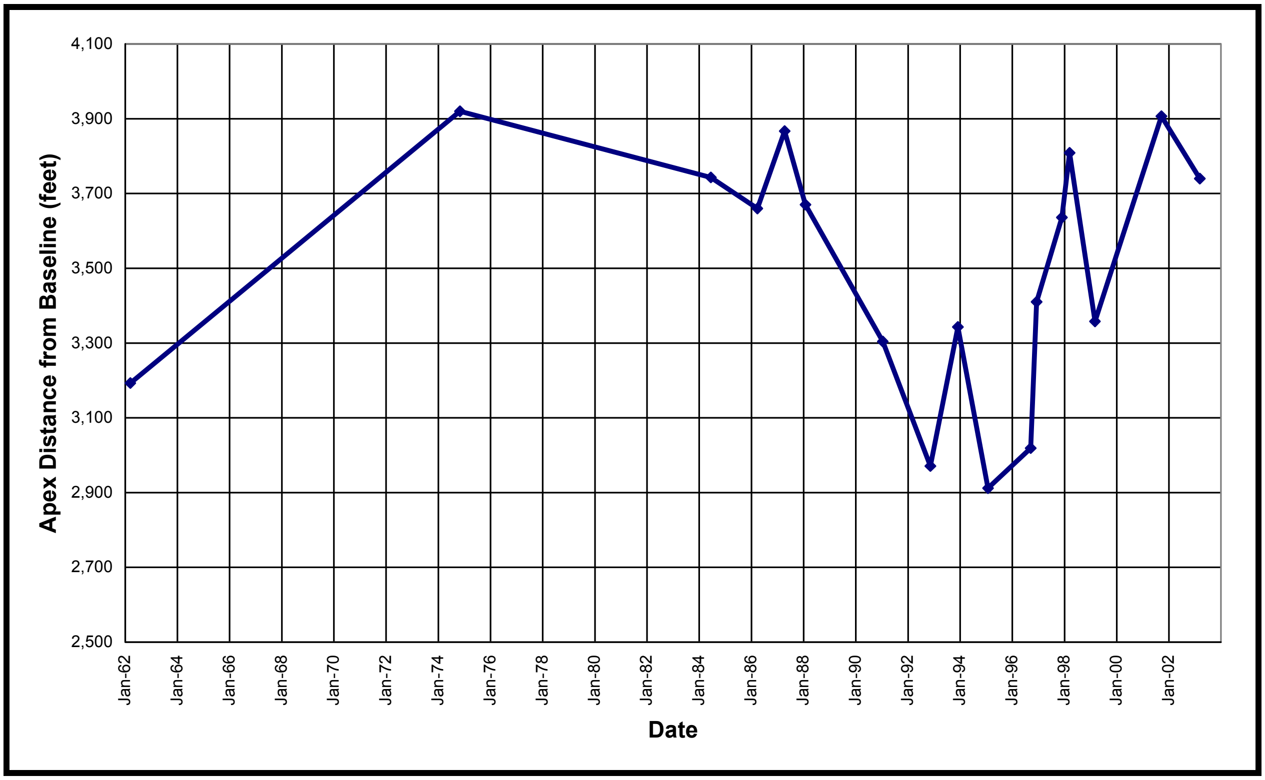


Figure 46. Offshore distance from the inlet baseline to the apex of the New River Inlet ebb tide delta (March 1962 to March 2003).

Horizontal Distance to Apex of Ebb Tide Delta

The horizontal location of the apex of the ebb tide delta, although somewhat dependent on the orientation of the ebb channel, provides an indication of the impacts of wave refraction patterns on the adjacent beaches. For example, if the apex is located more toward North Topsail Beach, the nodal point for sediment transport would be located farther southwest, affording a large portion of the north end of North Topsail Beach with protection against direct wave attack. As the distance to the apex from North Topsail Beach increases, the nodal zone would move to the northeast exposing more of the north end of North Topsail Beach to direct wave attack. Also, as discussed above, the movement of the channel and apex to the northeast is generally accompanied by the formation of marginal flood channels offshore of the extreme north end of North Topsail Beach, which increases the loss of sediment from North Topsail Beach into New River Inlet.

The horizontal location of the apex of the ebb tide delta between 1962 and 2003 measured from the reference line located between transects 16 and 17 is shown Figure 47. The apex of the delta migrated to the southwest between 1962 and January 1984, in conjunction with the movement of the ebb channel. The channel and apex of the delta began to shift back toward Onslow Beach in 1984 reaching its maximum distance (during the period of analysis) from the reference line around November 1997. The apex of the delta jumped back to the southwest between November

1997 and March 1998 as a result of the natural breaching of the channel (Figures 40 and 41) but resumed its northeast movement between March 1998 and March 2003.

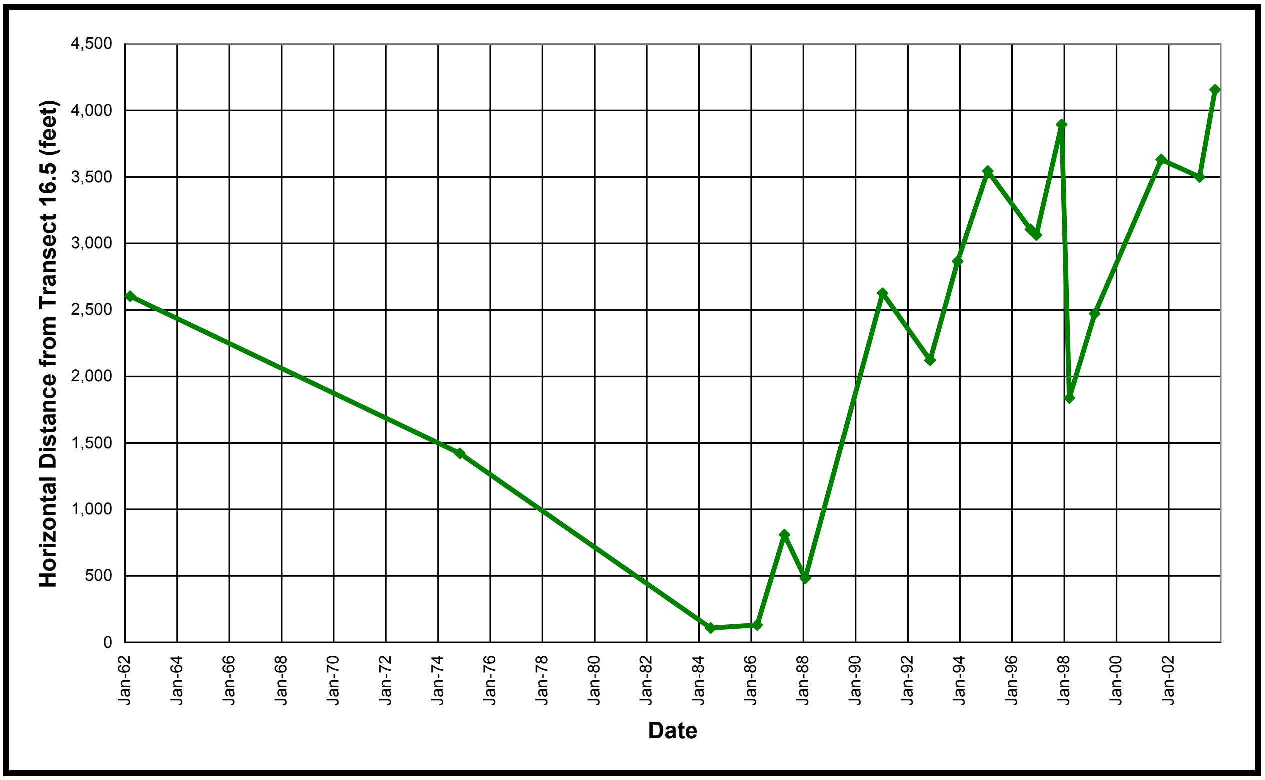


Figure 47. Horizontal distance from transect 16.5 (baseline station 1157+50) on North Topsail Beach to the apex of the ebb tide delta.

An aerial photo taken by the Corps of Engineers in October 2003 (Figure 48) seemed to indicate that the channel was shifting back to the southwest; however, the apex of the delta was located over 4,100 feet from the reference line, its greatest distance since 1962.

CPE obtained aerial photographs of North Topsail Beach and New River Inlet in February 2005 and conducted a hydrographic survey of the inlet in August 2005. Both the February 2005 aerial photos and the August 2005 survey showed the bar channel still oriented toward the southeast. The orientation of the New River Inlet ocean bar channel in August 2005 is shown in Figure 49, an oblique aerial photograph taken by the Corps of Engineers. Accordingly, the southwest shift in the bar channel that appeared to be occurring in October 2003 did not materialize.

Figure 48. October 13, 2003 aerial of New River Inlet taken by the Corps of Engineers showing apparent tendency of channel to shift its location to the southwest.

Figure 49. August 2005 aerial of New River Inlet showing orientation and alignment of the main bar channel (yellow dashed-line) toward the southeast. (Photo by Corps of Engineers).

Surface Area of Ebb Tide Delta

The surface area of the ebb tide delta of New River Inlet increased in size following the construction of the AIWW in the early 1930's and the channel connecting the AIWW with the City of Jacksonville in 1940 (Jarrett, 2002). The growth of the ebb tide delta, which was accompanied by an increase in the tidal prism of the inlet; seemed to stabilize by 1962 and, as shown in Figure 50, has fluctuated around an average size of 10.6 million square feet since that time. The portion of the ebb tide delta located southwest of the main channel (Area "A" in Figure 50) has generally followed the same trend as the total surface area with sub-area "A" representing approximately 40% of the total surface area o f the delta. The fluctuation in the size of the ebb tide delta is indicative of the periodic storage and release of littoral material that flows into the inlet from North Topsail Beach and Onslow Beach.

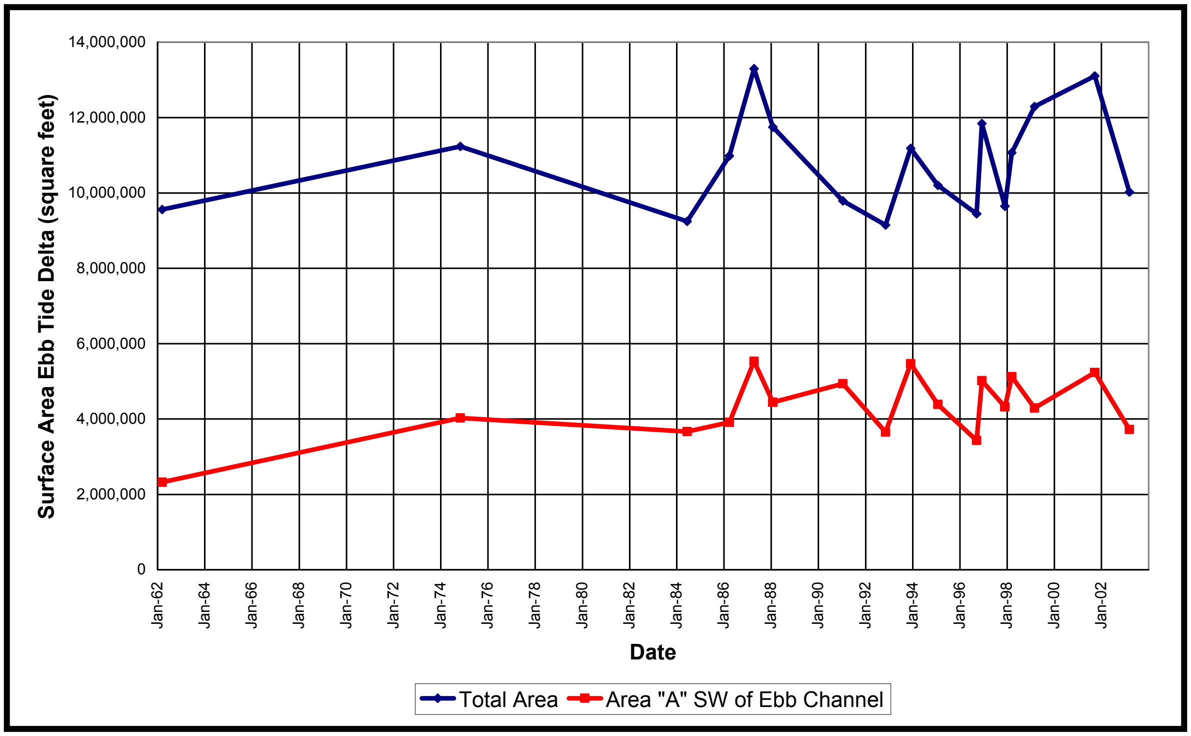


Figure 50. Surface area of New River Inlet ebb tide delta. Total area and area "A" on the southwest side of the bar channel (March 1962 to March 2003).

Summary of Geomorphic Analysis

The change in the behavior of the shorelines on the northeast end of North Topsail Beach and the southwest end of Onslow Beach correspond to the time when the main channel through the ebb tide delta of New River Inlet began to shift from a southwesterly alignment to a southeasterly alignment. The realignment of the ebb channel was accompanied by a shift in the apex of the ebb tide delta to the northeast or toward Onslow Beach. These changes in the configuration of the ebb tide delta modified sediment transport patterns on North Topsail Beach and exposed the northernmost end of the beach to direct wave attack. Prior to this shift in channel alignment and apex position, the northern end of North Topsail Beach benefited from the protection provided by the ebb tide delta with the section of the shoreline located between baseline stations 1115+00 and 1150+00 (transects 8 to 15) advancing an average of 210 feet between 1962 and 1984. Farther to the southwest, the shoreline between baseline stations 1080+00 and 1110+00 (transects 1 to 7) advanced an average of 52 feet during this period. Once the inlet channel and apex of the ebb tide delta began to shift toward Onslow Beach, the entire shoreline on the north end of North Topsail Beach between baseline stations 1080+00 and 1150+00 (transects 1 to 15) responded by receding at an average rate of 5.3 feet/year between 1984 and 2003. The shoreline between transects 22 to 33, located on Onslow Beach northeast of the inlet ebb tide delta, receded at an average rate of 7.9 feet/year between 1962 and 1984 with the recession rate increasing to 18.2 feet/year between 1984 and 2003, a time when the channel was oriented in a southeasterly direction.

During periods of southeasterly wave approach (the dominant wave direction) sediment is transported and deposited into New River Inlet at fairly high rates. When the direction of sediment transport reverses, i.e., waves approach from the southwest, the wave refraction phenomenon around the ebb tide delta would tend to transport some material immediately updrift of the inlet (i.e., on the Onslow Beach side) back toward New River Inlet with this material carried into New River Inlet by the marginal flood currents running parallel to the shoreline as well as by the main inlet channel. This combined loss of sediment into New River Inlet during all wave conditions could be partially responsible for the increased erosion rates on Onslow Beach when the channel is oriented toward the southeast.

Magnetometer and Sidescan Sonar Survey

Tidewater Atlantic Research, Inc. (TAR) was contracted by CPE to conduct a systematic magnetometer and sidescan sonar survey of New River Inlet and Cedar Bush Cut to locate and identify submerged cultural resources within the inlet complex. TAR conducted the field survey on 5 October and 6 November 2004. Analysis of the remote sensing data revealed a total of 111 magnetic and/or acoustic anomalies (targets) from the seaward edge of the ebb tide delta to the confluence of Cedar Bush Cut with the AIWW. Only 20 of the targets were located seaward of the gorge of New River Inlet (the deep water area located between North Topsail Beach and New River Inlet). The locations of the magnetic and/or acoustic anomalies are shown in Figure 51. The targets are color coded to indicate their potential historical significance with yellow targets rated low and red targets rated medium to high. Four (4) of the 20 anomalies located seaward of the inlet gorge were identified as having a medium to high potential association with shipwreck material and/or other submerged cultural resources. These 4 anomalies are inside the red circle in Figure 51. TAR concluded that these 4 anomalies could be associated with the remains of vessels and should be avoided if possible. If avoidance of the 4 targets is not possible, additional field investigations should be conducted to identify the characteristics of the targets.

Figure 51. Location of magnetic and/or acoustic anomalies in New River Inlet. Potential for historical significance indicated by color with yellow targets rated low and red targets rated medium to high (Tidewater Atlantic Research).

Recommended Channel Modification

The results of the geomorphic analysis strongly suggest that a channel oriented perpendicular to the adjacent shorelines (i.e. along an azimuth of approximately 150^{o}) and located closer to the north end of North Topsail Beach would provide positive shoreline benefits for the adjacent oceanfront shorelines. In order to avoid possible impacts on the 4 potentially significant archeological targets shown in Figure 51 the orientation of the proposed channel would be shifted slightly more toward the southwest along a 155^{o} azimuth. The approximate centerline of the proposed channel is shown in Figure 52.

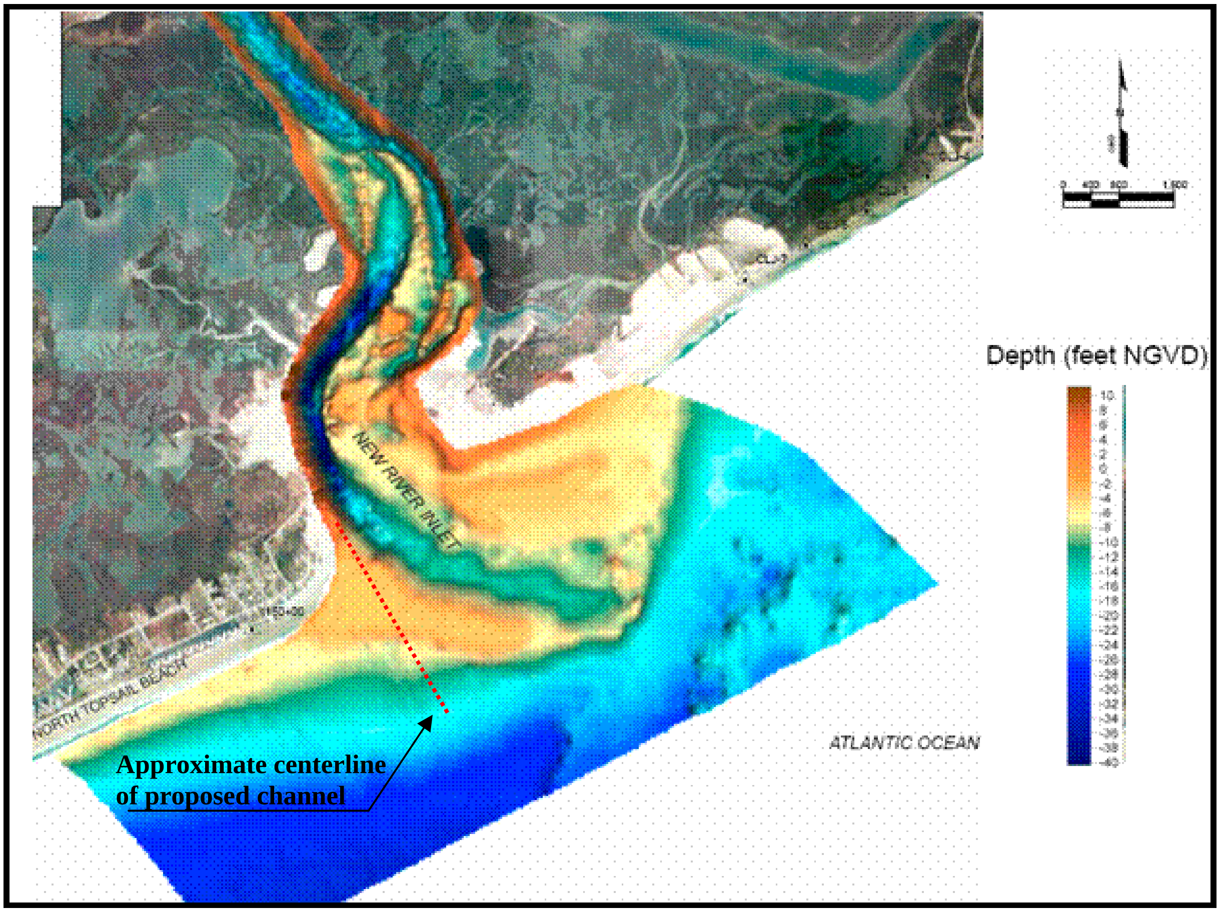


Figure 52. Approximate centerline of proposed new ocean bar channel in New River Inlet.

The impact of the new channel on the north end of North Topsail Beach should be a return to the accretionary shoreline trends observed prior to the movement of the ocean bar channel toward Onslow Beach and a shift of the channel alignment to the southeast. Shoreline recession rates on Onslow Beach will likely be reduced but not be eliminated. Realignment of the channel should result in a reconfiguration of the ebb tide delta with a large wedge of sediment located northeast of the new channel migrating onshore and merging with the extreme southwest end of Onslow Beach. The migration of this wedge of material could have a positive impact along the remainder of Onslow Beach. The reconfigured ebb tide delta could also develop linear bar complexes similar to the ones depicted on the January 1988 photo shown in Figure 38 resulting in the elimination of the marginal flood channels that presently exist off the north end of the beach.

Predictions of expected changes in the shape of the New River Inlet ocean bar and the accompanying impacts on the adjacent shorelines are presented later.

EXISTING SEDIMENT BUDGET

Introduction

A sediment budget, which provides an estimate of how material flows into and out of New River Inlet, was developed for existing conditions using the following input information:

(1) Shoreline change information developed by Dr. Cleary for the northeast end of North Topsail Beach between baseline stations 1080+00 and 1150+00 (transects 1 to 15) and the southwest end of Onslow Beach (transects 22 to 33) for the 1984 to 2003 time period.

(2) Historic shoreline change information for the central portion of Onslow Beach developed by the NC Division of Coastal Management.

(3) Adjustments in the shoreline change rates to account for the effects for rising sea level.

(4) Longshore littoral sediment transport rates computed for this study using wave information developed by the U.S. Army Corps of Engineers Coastal Hydraulics Laboratory for WIS Station AU2044.

(5) The relationship between shoreline orientation and sediment transport rates is shown in Figure 8. This figure was used to obtain initial estimates of littoral transport rates along the various shoreline segments north and south of New River Inlet. Some adjustments were made in the initial estimates in order to balance the sediment budget for some shoreline reaches as explained below.

(6) Volumetric sand losses from the frontal beach due to overwash on the southwest end of Onslow Beach based on the change in the size of overwash fans during the period of analysis.

(7) Volumetric changes on the ebb tide delta of New River Inlet were determined from a comparison of a detailed June 1978 hydrographic survey of New River Inlet (obtained by the Corps of Engineers) and the June 2003 hydrographic survey of the inlet (obtained by CPE for this study). The volume of material removed from Cedar Bush Cut by dredging over this same time period was added to the volume retained on the ebb tide delta to obtain an estimate of the total volume of littoral sediment trapped by the New River Inlet system.

(8) The volume of material removed from Cedar Bush Cut and deposited on the north end of North Topsail Beach during the shoreline change period used in the sediment budget analysis (1984 and 2003).

(9) Dredging of the inlet channel by the mini-hopper dredge CURRITUCK during the period covered by the inlet surveys (1978 to 2003). Since dredging by the CURRITUCK physically removes sediment from the ebb tide delta, the average annual volume removed by the CURRITUCK was added to the estimated volumetric change of the ebb tide delta determined

from the comparison of the 1978 and 2003 inlet surveys. Material reportedly removed from the inlet channel by the US Government sidecast dredges MERRITT and FRY are not included in the ebb tide delta volume change. This material remains on the ebb tide delta and would have been included in the comparison of the 1978 and 2003 inlet surveys.

Shoreline Volume Changes

Rates of volume change on the shoreline adjacent to New River Inlet were based on the average annual shoreline erosion rates by assuming that over the 19-year period (1984 to 2003) used for the sediment budget analysis; the entire active profile from the crest of the berm (elevation +6.0 feet) seaward to the -20-foot depth moved the same as the shoreline. That is, the displaced profile remains parallel to the previous profile. This assumption can be an error particularly over relatively short periods of time in which the foreshore beach responds faster than the deeper offshore portion. However, over relatively long periods of time, the assumption is believed to provide a reasonable order of magnitude estimate of equivalent volume change.

Adjustment for Sea Level Rise

The rate of sea level rise applicable to the North Topsail Beach area was determined from the average of sea level change rates observed at Sewells Point, VA (0.0145 ft/yr), Beaufort, NC (0.0122 ft/yr), and Charleston, SC (0.0108 ft/yr). The observed sea level trends are available from: http://tidesandcurrents.noaa.gov. The period of sea level observations used to establish these rates ranged from 78 years for Charleston, SC to 26 years for Beaufort, NC. The average rate of rise for these three stations is 0.0125 ft/yr. Shoreline changes due to a relative rise in sea level of 0.0125 ft/yr were based on the well known Brunn Rule (Brunn, 1962). Per Brunn theorized that as sea level rises, the beach profile attempts to reestablish the same bottom depths relative to the surface of the sea that existed prior to the rise in sea level. The quantity of material needed to reestablish the beach profile must be derived from erosion of the shore. This theory is expressed by the equation:

$$\Delta x = ab/(e+d)$$

where:

Δx = rate of shoreline recession due to sea level rise.
e = elevation of the beach berm (+ 6 feet NAVD).
d = limiting depth between predominant nearshore and offshore material transport characteristics (-20 feet NAVD).
a = rate of sea level rise (0.0125 ft/yr)
b = distance from the initial shoreline to the limiting depth.

The rate of shoreline erosion (Δx) associated with a sea level rise rate of 0.0125 ft/yr is equal to about 0.5 ft/year. Since this component of shoreline change is not associated with the longshore movement of littoral material, the shoreline change rates used in the sediment budget analysis were adjusted by 0.5 ft/year to yield an estimate of the change due to longshore sand transport inequalities. For example, the average rate of shoreline change between baseline stations

1080+00 and 1150+00 on the north end of North Topsail Beach averaged -5.3 ft/year from 1984 to 2003. The adjusted shoreline change rate used in the sediment budget analysis was -4.8 ft/year resulting in an equivalent volume loss from the 7,000-foot beach segment of 34,000 cubic yards/year.

Longshore Sediment Transport Rates

The rate of sediment transport to the southwest and northeast on the north end of North Topsail Beach was based on a shoreline orientation of N 60^{o} E, which are 522,000 cy/yr to the southwest and 297,000 cy/yr to the northeast (Figure 8). These transport rates are shown on the boundary of the North Topsail Beach reach in Figure 53. Northeast transport off the extreme north end of North Topsail Beach that flows directly into New River Inlet was based on a shoreline orientation of N 66^{o} E due to the shoreline bulge associated with the effects of the ebb tide delta in this area. For this shoreline orientation, the northeast transport off North Topsail Beach into New River Inlet is 270,000 cy/yr (from Figure 8). Transport rates along Onslow Beach were initially based on the respective orientation of the shoreline within the two reaches; however, the computed transport rates were adjusted to balance the volume of sediment moving into and out of each reach. The adjustment in the sediment transport rates on Onslow Beach were made following the computation of the volume of sediment naturally bypassing to the north and south around New River Inlet. The computed natural bypassing quantities are indicated by dashed arrows in Figure 53. The adjustments made in the transport rates on Onslow Beach included an increase in the southwesterly transport by 10% above the rate based on the shoreline orientation and a reduction in the northeast transport by 8%. These final adjusted transport rates on Onslow Beach are shown in Figure 53.

Overwash Losses – South End Onslow Beach

The overwash fan on the south end of Onslow Beach was measured from the aerial photos and found to cover and area 4,550 along and 900 feet across the island. An average depth of the fan of 2.0 feet was assumed resulting in a total overwash volume of 303,000 cubic yards since 1984. This represents an average rate for the 1984 to 2003 shoreline change period used in the sediment budget analysis of 16,000 cy/yr.

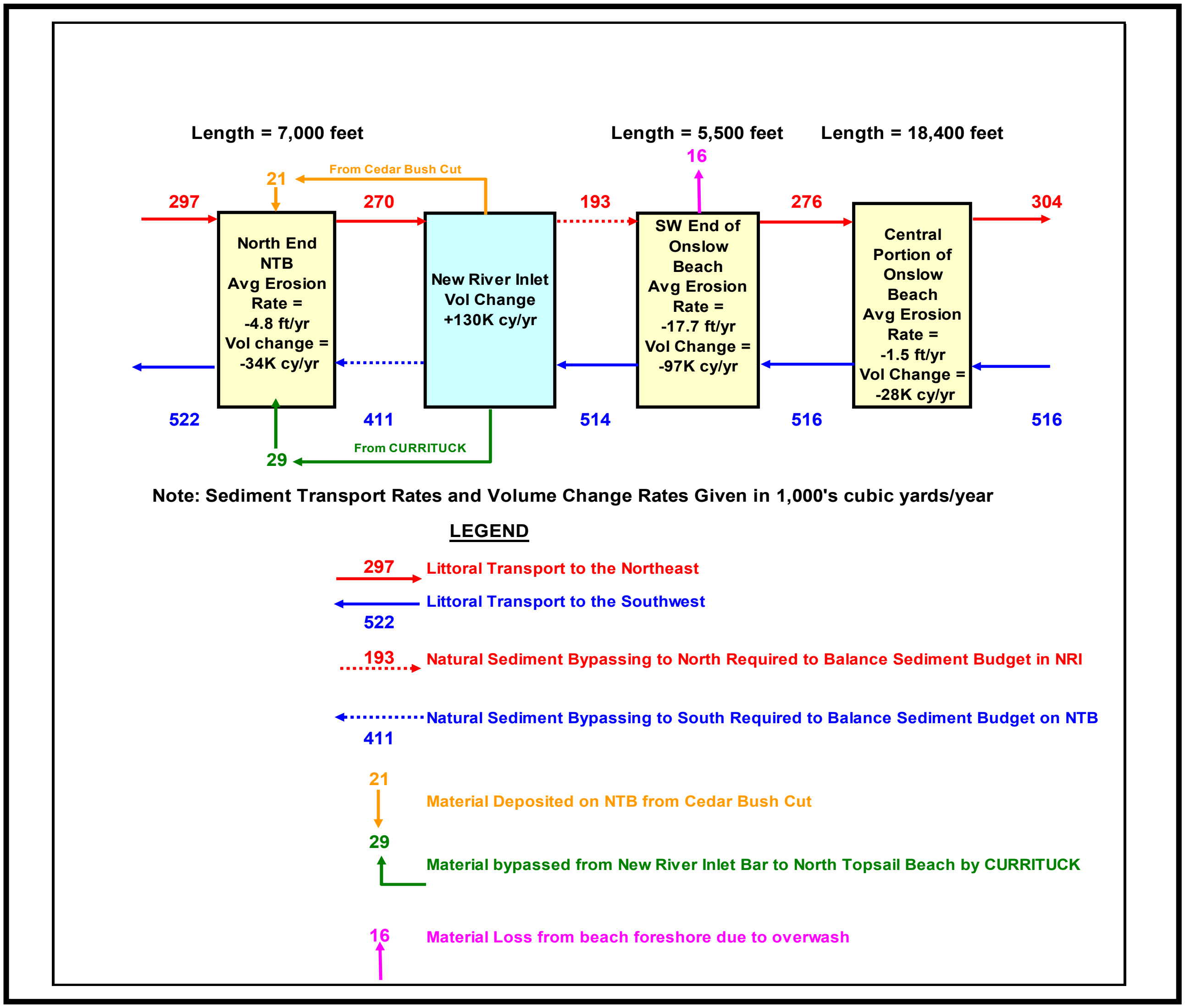


Figure 53. Existing sediment budget for New River Inlet and adjacent beaches.

Volume Change – New River Inlet

The volume of littoral sediment removed from the littoral system by New River Inlet was based on the change in volume of material on the ebb tide delta of New River Inlet determined by comparing the June 1978 hydrographic survey obtained by the Corps of Engineers and the June 2003 hydrographic survey conducted by CPE and dredging records in Cedar Bush Cut over the same time period. The volume change on the ebb tide delta was computed by comparing cross-sections across the ebb tide delta spaced at 500-foot intervals. The total volume change over the 25 year period was an accumulation of 1,324,000 cubic yards or an average accumulation of 53,000 cy/yr. Dredging in Cedar Bush Cut averaged 48,000 cy/yr over this same time period resulting in a total average accumulation in the New River Inlet system of 101,000 cy/yr.

Dredged Material Removed from the Ebb Tide Delta of New River Inlet

The majority of maintenance dredging in New River Inlet is performed by sidecast dredges, which do not remove material from the inlet system. However, 765,500 cubic yards was removed by the mini-hopper dredge CURRITUCK between 1978 and 2003 which represents an average rate of removal of 29,000 cubic yards/year. Accordingly, in the absence of dredging by the CURRITUCK, the sediment accumulation in the New River Inlet system would have totaled 130,000 cubic yards/year between June 1978 and June 2003.

The CURRITUCK deposited the material off the north end of North Topsail Beach in water depths between 10 and 15 feet or within the limits of the active beach profile. The insertion of this material represents a net gain for the north end of North Topsail Beach (Figure 53).

Cedar Bush Cut Dredged Material Deposited on North Topsail Beach

The shoreline change period used for the sediment budget extends from 1984 to 2003. These shoreline changes represent net changes determined from aerial photos and include positive impacts of the periodic disposal of material from maintenance dredging in Cedar Bush Cut. Accordingly, the volume of material placed on North Topsail Beach during this period was added to the sediment budget. Between 1984 and 2003, the average amount of material deposited on North Topsail Beach was 21,000 cy/yr. This amount of artificial sand bypassing is shown in Figure 53.

Summary Existing Sediment Budget

Of the total volume of littoral material transported into New River Inlet each year (gross transport) is equal to 784,000 cubic yards. Of this total 52.4% (411,000 cy/yr) is naturally bypassed to the north end of North Topsail Beach with 24.6% (193,000 cy/yr) moving naturally back onto the south end of Onslow Beach. Artificial bypassing from Cedar Bush Cut and nearshore disposal by the CURRITUCK increased the total amount of material bypassed to North Topsail to 461,000 cy/yr or 58.8% of the gross transport.

HYDRODYNAMIC MODEL

Model Description

The potential changes in the flows and circulation patterns in New River Inlet and the connecting channels associated with modifications in the main inlet channel were evaluated with a numerical model know as ADCIRC (Advanced Three-Dimensional Circulation Model for Shelves, Coasts, and Estuaries) developed by the Corps of Engineers (Leuttich, *et al*., 1992). The boundaries of the model (model domain) and color coded bathymetry are shown in Figure 54. The configuration of the ebb tide delta of New River Inlet included in the model was represented by the August 2005 hydrographic survey of the inlet obtained by CPE. During the August 2005 survey, the ebb channel was oriented along an azimuth of 103^{o}, or toward Onslow Beach. Details of the numerical model investigation are summarized below.

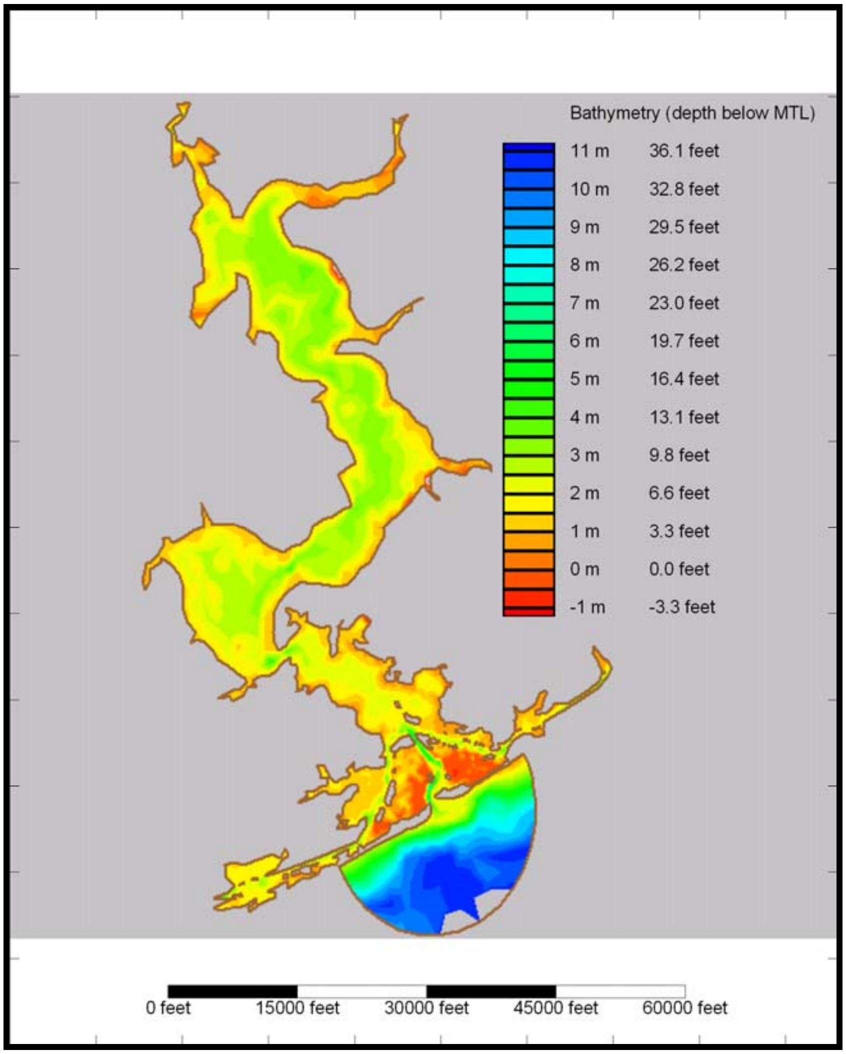


Figure 54. Numerical model boundaries.

Model Calibration and Channel Alternatives

The numerical model was calibrated for tide conditions observed during July 2003. Tide gage locations are shown in Figure 55.

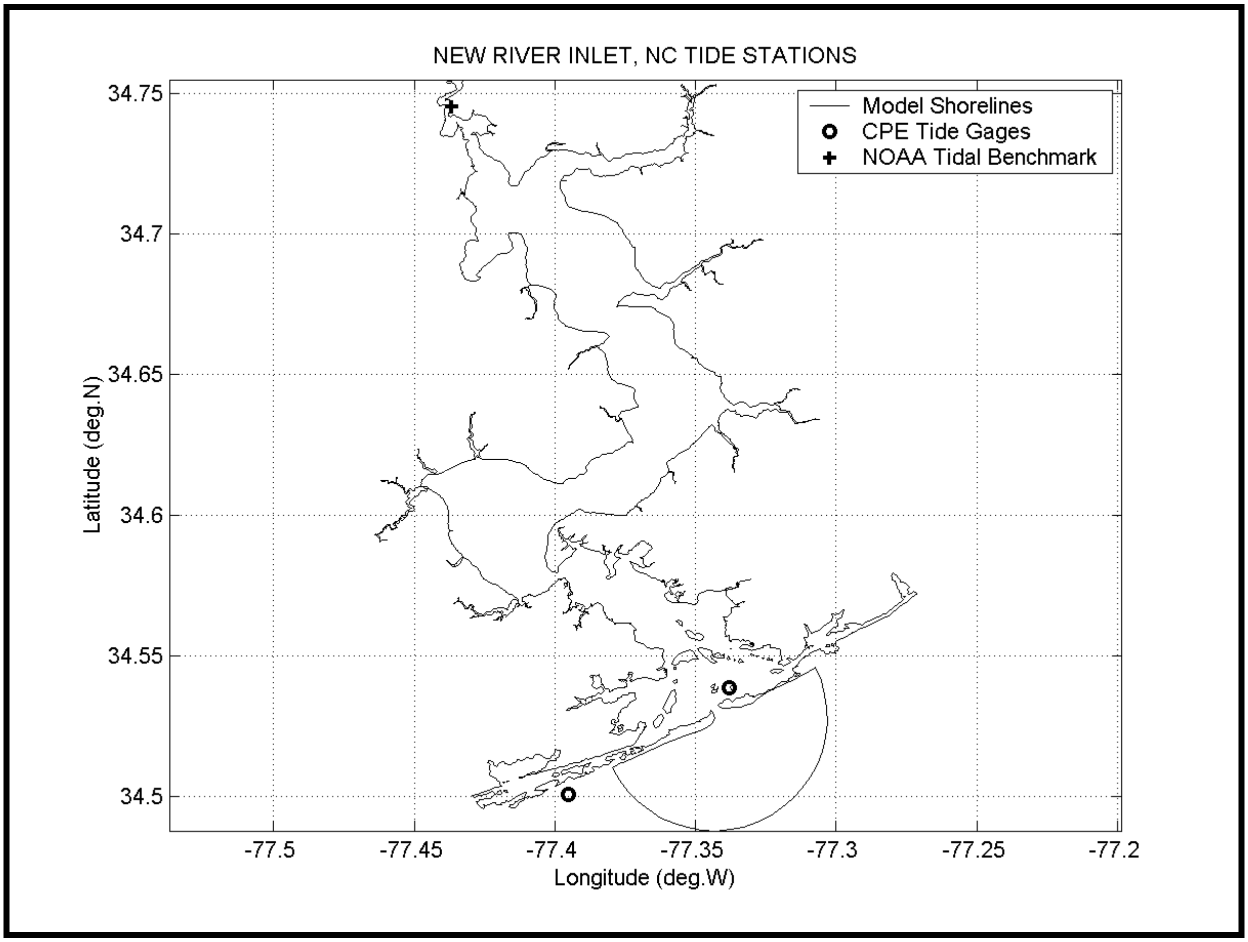


Figure 55. Tide gage locations.

Computer simulations were run to represent existing conditions and 3 channel alternatives. All channel alternatives had a depth of -18 ft NAVD and bottom widths of 300 ft, 400 ft, and 500 ft, respectively and would begin in the existing gorge of New River Inlet and extend along a 155° azimuth to the -18 ft NAVD depth contour in the ocean. The -18 ft NAVD bottom depth was selected for all alternatives since material below this depth appears to contain concentrations of gravel that would not meet the proposed new State sediment standards for beach nourishment material. Also, the shell content below -18 ft NAVD is relatively high and close to the limit that would be allowed by the proposed State borrow material standards. Shallower depths were not evaluated due to limitations on minimum digging depths associated with the type of dredge plant likely to be required to construct the channel. In this regard, the proposed channel would extend seaward across the COLREGS line which would require construction of the new channel to be performed by an ocean certified dredge. Most dredges with this classification have minimum digging depths of 15 feet below mean low water or -18 ft NAVD in the case of New River Inlet.

The bottom width at the start point of each alternative was 200 feet with the channel width increased by 100 feet every 100 feet along the channel centerline. In this regard, the 300-ft wide channel would reach its full width 100 feet seaward of the start point while the full width of the 500-ft channel would be reached 300 feet from the start point. A typical example of the channel alternatives is provided in Figure 56 which shows the channel centerline, bottom width, and side slope intercepts for Channel Alternative 3, the 500-foot wide channel. Station 10+00 on the centerline corresponds to the inlet gorge and the begin point of each channel. Note that the side slopes of all three alternatives were assumed to be 1V:5H (1 Vertical to 5 Horizontal). The volume of material that would be removed to construct the three channel alternatives are as follows:

300-ft x -18 ft NAVD	413,800 cubic yards
400-ft x -18 ft NAVD	527,600 cubic yards
500-ft x -18 ft NAVD	635,800 cubic yards

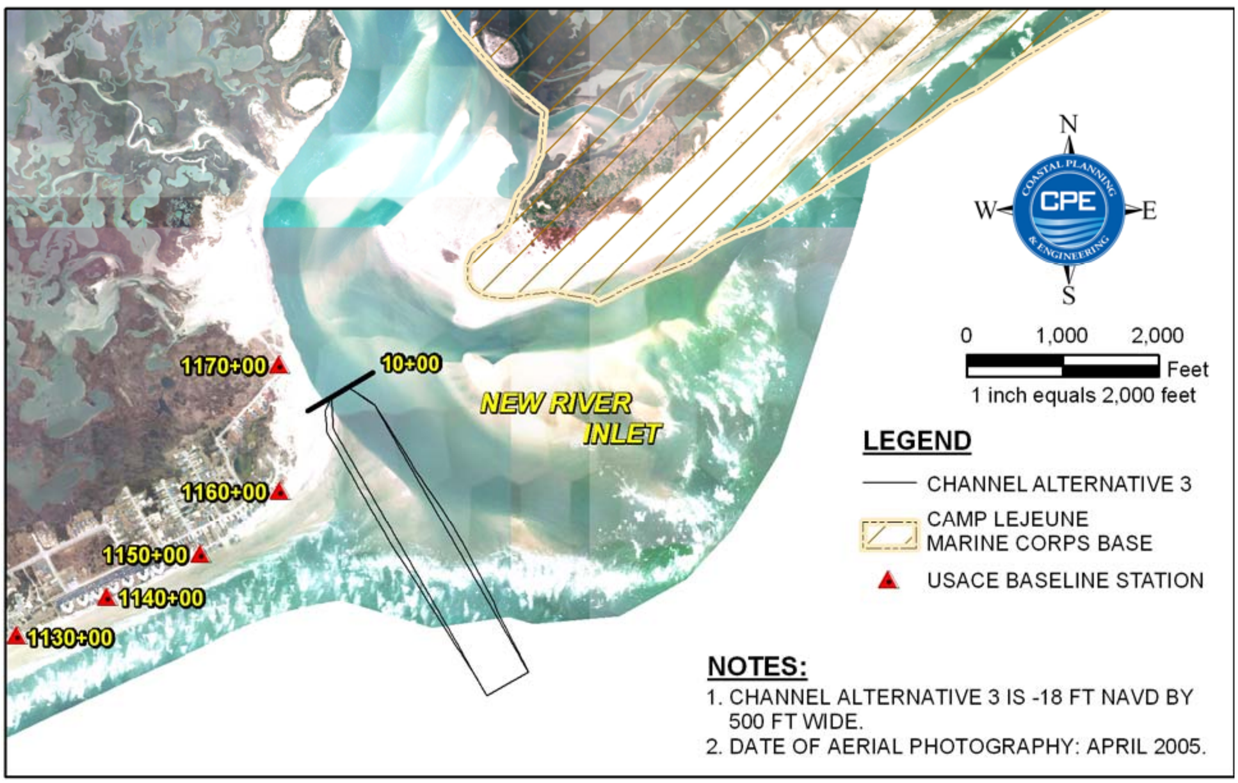


Figure 56. Channel Alternative 3 showing bottom width and side slope intercepts.

Presentation of Model Results

Flows in and out of New River Inlet were determined across 3 ocean transects (NE, ES, and SW) shown in Figure 57. Transect SW represents the southwest side of the ebb tide delta located off the north end of North Topsail Beach while Transect ES represents the middle portion of the ebb tide delta and Transect NE the northeast side of the delta. The distribution of ebb and flood flows throughout the interior portions of the inlet complex were computed for 5 transects designated as M-NW, M-SW, M-SE, M-NE, and C shown in Figure 57. Transect C is located across Cedar Bush Cut while the other four transects parallel marsh shorelines adjacent to Cedar Bush Cut.

Figure 57. Model flow transects.

Tidal Prism Comparison

Comparisons of the total flow or tidal prism through New River Inlet (sum of flow volumes through transects NE, ES, & SW) for the existing condition and the three alternatives are given in Table 7. The distribution of ebb and flood volumes through the various marsh transects is given in terms of the percent of the total entrance ebb and flood tidal prisms in Table 7.

Flood Phase

Flood tidal prisms through the New River Inlet entrance for the three alternatives were all within 2% of the flood tidal prism for the existing condition. The relatively small differences are not significant and can be explained by computational accuracy associated with the model results. The distribution of flood flow through the 3 entrance transects (NE, ES, & SW) was also similar to the existing condition, however, flood volumes through transect NE, located on the Onslow Beach side of the inlet, were reduced by 13% to 17% for all three alternatives. The differences in flood volumes through transect SW, located on the North Topsail Beach side of the inlet, were relatively small and probably within the accuracy of the model and therefore judged to be insignificant. The distribution of flood flows through the marsh transects were also comparable to the existing condition. The primary difference for the marsh transects during flood was a slight shift in the percentage of flow through transects M-NE and a comparable reduction in the percent of flow through transect M-NW for Alternatives 1 and 2. These small differences may be due to the accuracy of the model results since the distribution through all of the marsh transects for Alternative 3, the largest channel modification evaluated, was the essentially the same as the existing condition.

Table 7. Comparison of tidal volumes (cubic feet) passing through model transects, existing condition and channel Alternatives 1, 2, and 3.

Condition	Transect								
	NE	ES	SW	Entrance Tidal Prism	M-NW	M-SW	M-SE	M-NE	C
Ebb Volume (cubic feet)					**Percent Total Ebb Tidal Prism**				
Existing	$2.17x10^8$	$5.43x10^8$	$0.24x10^8$	$7.84x10^8$	26.8%	6.0%	18.7%	6.1%	42.4%
Alt 1	$0.81x10^8$	$6.78x10^8$	$0.20x10^8$	$7.79x10^8$	31.9%	9.5%	14.1%	6.4%	38.1%
Alt 2	$0.33x10^8$	$7.39x10^8$	$0.12x10^8$	$7.83x10^8$	32.8%	9.2%	13.7%	6.4%	37.9%
Alt 3	$0.46x10^8$	$7.14x10^8$	$0.12x10^8$	$7.72x10^8$	25.8%	5.8%	21.7%	6.0%	40.7%
Flood Volume (cubic feet)					**Percent Total Flood Tidal Prism**				
Existing	$2.01x10^8$	$2.66x10^8$	$1.31x10^8$	$5.98x10^8$	14.8%	1.7%	0.7%	13.7%	69.1%
Alt 1	$1.75x10^8$	$2.41x10^8$	$1.40x10^8$	$5.56x10^8$	12.5%	0.7%	0.7%	15.3%	70.8%
Alt 2	$1.67x10^8$	$2.65x10^8$	$1.32x10^8$	$5.64x10^8$	11.9%	0.8%	0.7%	15.5%	71.1%
Alt 3	$1.68x10^8$	$2.72x10^8$	$1.52x10^8$	$5.92x10^8$	15.4%	1.7%	0.1%	13.5%	69.3%

Ebb Phase

The model results for the ebb phase indicate the ebb tidal prisms for the three alternatives were equal to the existing condition. For all three alternatives, the deeper wider channel across the inlet's ebb tide delta captured the majority of ebb flow (transect ES). The major difference in the ebb flow through the entrance for the three alternatives compared to the existing condition was a significant reduction in ebb flow across transect NE, the Onslow Beach side of the inlet and reduction in the ebb flow volumes across transect SW for Alternatives 2 and 3. As was the case for the flood phase, there were only small differences in the percent of ebb flow across the various marsh transects.

Implications of Model Results

Modification of the inlet bar channel did not have any significant impact on flow circulation patterns through the marsh areas located between the inlet and the AIWW during both ebb and flood. The modified channels did not appreciably change the total volume of water entering the inlet (flood phase) from the North Topsail Beach side (transect SW). Not unexpected was the higher concentration of ebb flow through transect ES for the three channel alternatives compared to the existing condition. One of the more significant results of the model evaluation was a reduction in the ebb flow volume and associated reduction in ebb velocities through transect NE for Alternatives 2 and 3. This change should generate a favorable reconfiguration of the ebb tide delta with the onshore movement of material presently "trapped" in the northeast portion of the inlet's ebb tide delta.

Channel Selection

Based on the numerical model results discussed above, Alternative 3, the 500-foot wide x -18 ft NAVD channel; was judged to provide the hydrodynamic changes in flow patterns through the ocean entrance that would be conducive to desired changes in the configuration of the ebb tide delta. The flood and ebb tidal prism for Alternative 3 were not significantly different from the existing condition and the distribution of ebb and flood flows through the interior marsh transects was also essentially the same as the existing condition.

CHARACTERISTICS OF CHANNEL MATERIAL

Composite Characteristics of the Channel Material

Details of the geotechnical investigations conducted in New River Inlet are presented in Appendix C. Vibracores were taken in New River Inlet on three separate occasions, July 2003, July 2007, and November 2008. The November 2008 vibracores, which included 7 vibracores located within the footprint of the proposed channel, were taken in response to sediment compatibility criteria adopted by the State of North Carolina in February 2008. The State criteria requires a minimum of 10 cores within proposed borrow areas. The November 2008 vibracores revealed discontinuous layers of clay at varying depths within the proposed channel corridor which had not been identified by the previous geotechnical investigations. As a result, consideration was given to conducting additional geotechnical investigations to see if an alternative channel position and alignment could be developed to avoid the clay. After consultations with the Town of North Topsail Beach, a decision was made to retain the channel in its preferred position and alignment which, according to the geomorphic study of the inlet presented above, would produce the desired positive shoreline impacts on the north end of the town.

Based on the 2005 hydrographic survey of the inlet, a total 635,800 cubic yards of material is located within the preferred channel corridor. In order to avoid the clay layers, the channel was divided into five (5) subsections with variable depths of cut based on the elevation of the clay layer within each subsection. The amount of beach compatible material located above the clay layers was estimated to be 544,400 cubic yards with the remaining 91,400 cubic yards consisting of clay and shell. The beach compatible material would be pumped to the beach to construct the beach fill along the northern section of the town and the incompatible material deposited in an upland disposal site located at the juncture of the AIWW and New River Inlet (Figure 26 in Appendix C).

The composite characteristics of the beach compatible material located above the clay layer are presented in Table 8 along with the limits imposed by the state sediment compatibility criteria. As can be seen, the material lying above the clay layer meets all of the state sediment compatibility standards.

Table 8. Composite characteristics of the New River Inlet material located above the clay layer within the preferred channel corridor.

	% Silt	% Carbonate	% Granular	% Gravel	Volume (cubic yards)	Acreage
Native Beach	1.5	25.8	1.07	0.43		
State Standard Allowance above native	5	15	5	5		
State Standard Cutoff	6.5	40.8	6.07	5.43		
Channel Borrow Area*	1.53	15.7	5.38	3.64	544,400	45.0

* These values represent the sand fraction above the clay layer in New River Inlet.

CHANNEL SHOALING ANALYSIS

Introduction

The inlet management plan for New River Inlet assumes that once the new channel is constructed through the ebb tide delta, the Town of North Topsail Beach would continue to maintain the channel in its central location, primarily to induce favorable shoreline readjustments associated with a reconfigured ebb tide delta. A secondary benefit of the inlet management plan should be a more reliable navigation channel through the New River Inlet ocean bar.

The new channel will immediately begin to shoal following its relocation. Over time, the shoaling would be expected to reinitiate the movement of the channel alignment back toward Onslow Beach. Since maintaining the preferred alignment and position of the channel the key element in providing shoreline protection immediately south of New River Inlet, two thresholds are established to dictate when channel maintenance is required. The first threshold is based on the degree of shoaling in the new channel while the second is based on migratory tendencies of the new channel.

<u>Channel Shoaling Threshold</u>. Maintenance of the new channel would be performed when the volume of shoal material is equal to or greater than 85% of the initial dredge volume. While the new channel position and alignment may still hold with this degree of shoaling, once the channel shoals to this extent, this threshold is based on the assumption the channel would soon begin to migrate toward the north away from the preferred position and alignment.

Channel Position Threshold. The new channel would be constructed to a bottom width of 500 feet which essentially represents a preferred channel corridor. Should the entire channel migrate either to the north or south outside the preferred corridor, the channel would returned to the preferred corridor.

Estimates of possible shoaling rates in the news channel are provided below.

Estimate of Channel Shoaling

The natural depth and width characteristics of an inlet ocean bar channel are dictated by prevailing currents, tides, wave action and, sediment transport. When an artificially deep or wide channel is cut through the ebb tide delta, these factors will immediately begin to work toward restoring the dimensions of the channel to its natural depth and width. Accordingly, an estimate was made of the rate of shoaling likely to occur in the new channel should it be dredged to a depth of 18 feet below NAVD (-15 ft MLLW) over a width of 500 feet. In addition to providing shoal quantities, the analysis provides an estimate of the time the channel would maintain controlling depths equal to or greater than the authorized 6-foot MLW (approximately -9 ft NAVD) presently authorized for New River Inlet. Details of the channel shoaling analysis, which are based on a procedure developed by the Wilmington District Corps of Engineers (USACE, 1989) are presented below.

The rate of shoaling that occurs in a channel dredged across the ebb tide delta of a tidal inlet is a function of the depth of the dredged channel relative to the normal depth of the bar channel. The potential for sediment transport in a dredged channel relative to the potential for sediment transport in the natural channel is given by the transport ratio as follows:

$$\text{Transport Ratio} = (d_1/d_2)^{5/2}$$

where: d_1 = natural bar channel depth below mean tide level (MTL)
d_2 = depth of dredged channel below MTL
(Note: See Figure 58 for definition of terms)

The depths d_1 and d_2 are average depths in the bar channel determined from the gorge of the inlet to the seaward edge of the ebb tide delta across the full width of the channel.

The transport ratio is a measure of the amount of littoral material that would be transported out of the dredged channel once it deposits in the channel. The amount of material that would remain in the channel and thus cause shoaling is a function of the Sediment Retention Factor (SRF) defined as:

$$SRF = 1 - (d_1/d_2)^{5/2}$$

The sediment retention factor only applies to that portion of the gross longshore transport (gross longshore transport = the sum of material moving toward the inlet from both sides) which is intercepted by the channel. Sediment transport past a tidal inlet occurs around the sloping seaward face of the ebb tide delta as well as a result of changes in the bar channel position and alignment. Since the latter bypassing mechanism occurs over a relatively long period of time, the channel shoaling analysis only considers sediment moving past the inlet around the seaward face of the ebb tide delta. Inherent in this analysis is the assumption that the dredged channel position remains fixed. As the channel is cut deeper into the ebb tide delta, a larger percentage of the gross longshore transport would become available to shoal the channel with the remainder of the material moving past the inlet below the bottom of the dredged channel. The degree to which the dredged channel prevents the movement of sediment around the seaward face of the ebb tide delta is provided by the depth ratio (D_R) defined as:

$$D_R = (d_2-d_1)/(d_3-d_1)$$

where: d_1 and d_2 have been previously defined and
d_3 = Depth of closure of the ebb tide delta with the ocean bottom

The percentage of the gross littoral transport moving toward the inlet during any time interval that would shoal the deepened channel is a function (f) of the product of the sediment retention factor and the depth ratio as follows:

$$V_R=f(D_R \times SRF)$$

where: V_R = (channel shoal volume/littoral transport rate)

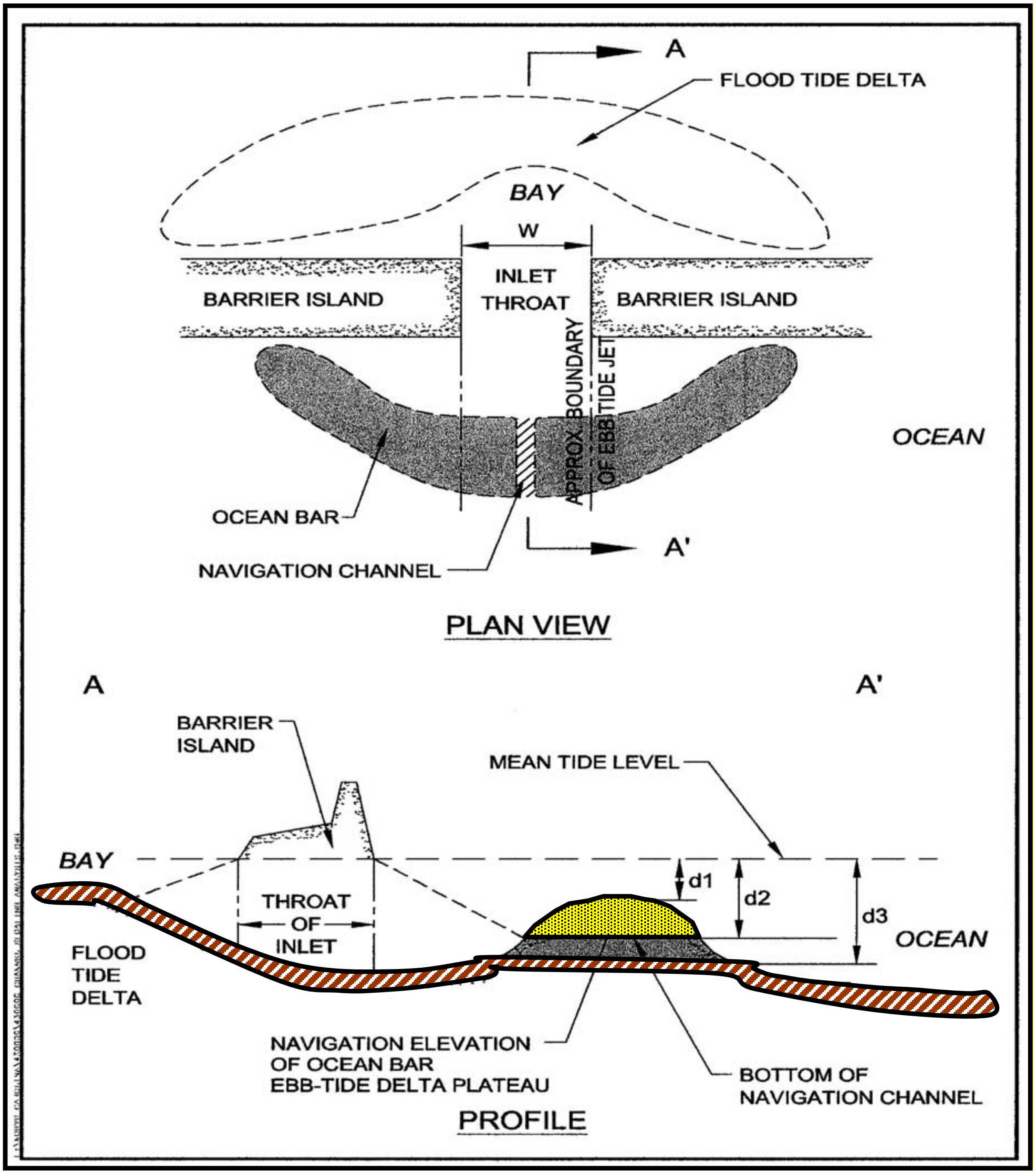


Figure 58. Definition sketch for inlet channel shoaling analysis.

Since the functional relationship between the depth ratio (D_R) and sediment retention factor (SRF) is not known, the Corps of Engineers developed an empirical relationship using data from 5 inlets in the Wilmington District, namely, Oregon Inlet, Beaufort Inlet, New River Inlet, Masonboro Inlet, and Lockwoods Folly Inlet. Note that the data used for Masonboro Inlet was for a dredged channel that predated the construction of the dual jetty system. The data used by the Corps of Engineers is given in Table 9 along with additional data points for Bogue Inlet that were added by CPE from its studies of Bogue Inlet performed for the Town of Emerald Isle (CPE, 2004).

For purposes of this report, five (5) additional data points for New River Inlet were added to the empirical dataset based on channel shoaling characteristics and dredging records between March 2002 and July 2003. A plot of the change in the volume of material in the channel between March 2002 and July 2003, which was determined from 11 channel surveys during the period, and the cumulative amount of material reportedly removed from the channel by the dredges MERRITT and FRY are shown in Figure 59. The five additional data points for New River Inlet derived from this survey and dredging data are highlighted in Table 9. A plot of all of the data points and the revised empirical shoaling relationship are shown in Figure 60.

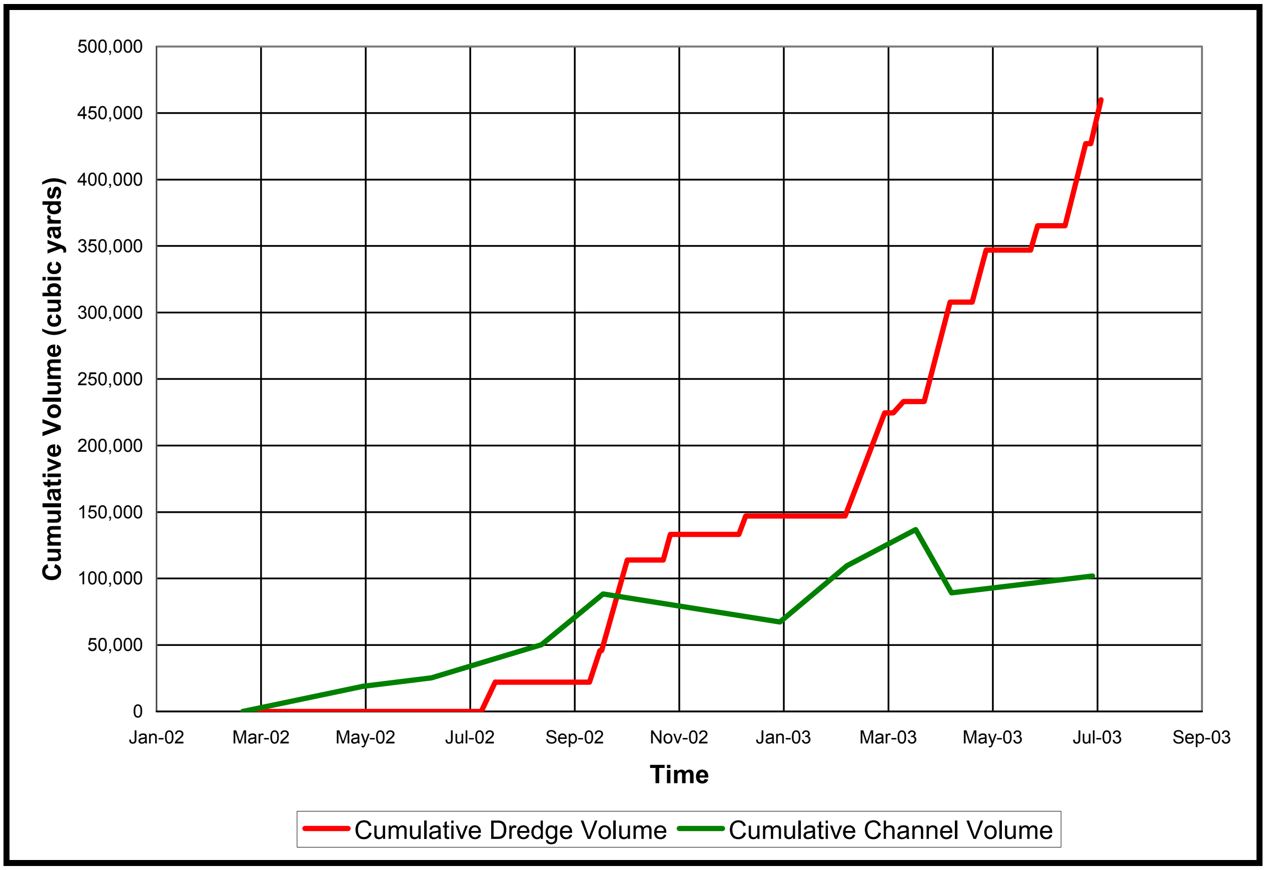


Figure 59. New River Inlet cumulative dredge volume and cumulative change in volume of material in the bar channel (March 2002 to July 2003).

Table 9. Data used to develop the ocean bar channel empirical shoaling relationship.

Inlet	Survey Dates	d_1 mtl	d_2 mtl	d_3 mtl	SRF = $1-(d_1/d_2)^{5/2}$	$D_r = (d_2-d_1)/(d_3-d_1)$	D_r x SRF	Channel Shoal Vol (cy)	Gross Transport (cy)	V_R (%)
Oregon	3/13/75 - 7/9/75	10.5	16.0	31.0	0.651	0.268	0.175	121,540	487,960	24.9%
	9/23/75 - 12/12/75	10.5	15.8	31.0	0.640	0.259	0.165	184,080	699,050	26.3%
Beaufort	Aug 1937 - 1950	17.5	34.0	36.5	0.810	0.868	0.703	507,800	860,000	59.0%
	2/5/64 - 6/23/64	17.5	36.6	36.5	0.842	1.005	0.846	258,120	337,030	76.6%
	10/10/67 -1/22/68	17.5	39.3	36.5	0.868	1.147	0.996	172,850	255,050	67.8%
	11/18/70 - 3/24/71	17.5	38.3	36.5	0.859	1.095	0.940	334,900	353,600	94.7%
	4/17/72 - 6/13/72	17.5	37.3	36.5	0.849	1.042	0.885	97,760	125,820	77.7%
	2/6/74 -5/21/74	17.5	40.7	36.5	0.879	1.221	1.073	282,420	260,610	108.4%
Masonboro	10/6/59 -12/8/59	6.9	16.8	31.9	0.892	0.396	0.353	72,830	184,020	39.6%
	12/8/59 -5/13/60	6.9	14.9	31.9	0.854	0.320	0.273	102,050	584,120	17.5%
Lockwoods Folly	6/20/65 - 7/22/65	5.6	9.8	20.1	0.753	0.290	0.218	8,160	60,420	13.5%
	2/9/76 - 4/22/76	5.6	11.7	20.1	0.842	0.421	0.354	27,670	139,360	19.9%
	4/22/76 - 9/30/76	5.6	10.1	20.1	0.771	0.310	0.239	27,850	272,500	10.2%
New River Inlet	10/31/79 - 3/10/80	4.5	11.2	25.0	0.898	0.327	0.293	41,200	408,400	10.1%
	3/10/80 - 4/16/80	4.5	9.9	25.0	0.861	0.263	0.227	16,000	106,800	15.0%
	6/5/80 - 8/13/80	4.5	11.1	25.0	0.895	0.322	0.288	24,300	175,900	13.8%
	10/7/80 - 3/11/81	4.5	10.5	25.0	0.880	0.293	0.257	32,500	456,300	7.1%
	5/7/81 - 6/23/81	4.5	9.9	25.0	0.861	0.263	0.227	16,000	123,900	12.9%
	8/24/81 - 10/9/81	4.5	11.5	25.0	0.904	0.341	0.309	10,800	107,800	10.0%
	10/9/81 - 3/17/82	4.5	10.5	25.0	0.880	0.293	0.257	25,600	470,400	5.4%
	3/6/02 - 4/15/02	4.5	9.6	25.0	0.850	0.249	0.211	18,866	118,885	15.9%
	4/15/02 - 6/24/02	4.5	9.0	25.0	0.823	0.220	0.181	6,443	68,432	9.4%
	6/24/02 - 7/18/02	4.5	9.3	25.0	0.837	0.234	0.196	9,370	28,953	32.4%
	10/2/02 - 1/13/03	4.5	8.1	25.0	0.770	0.176	0.135	29,669	254,941	11.6%
	1/13/03 - 2/21/03	4.5	8.1	25.0	0.770	0.176	0.135	42,188	105,325	40.1%
Bogue	10/19/96 - 7/25/97	8.0	10.1	25.0	0.442	0.124	0.055	32,579	641,243	5.1%
	7/25/97 - 10/9/97	8.0	11.0	25.0	0.549	0.176	0.097	33,076	174,003	19.0%

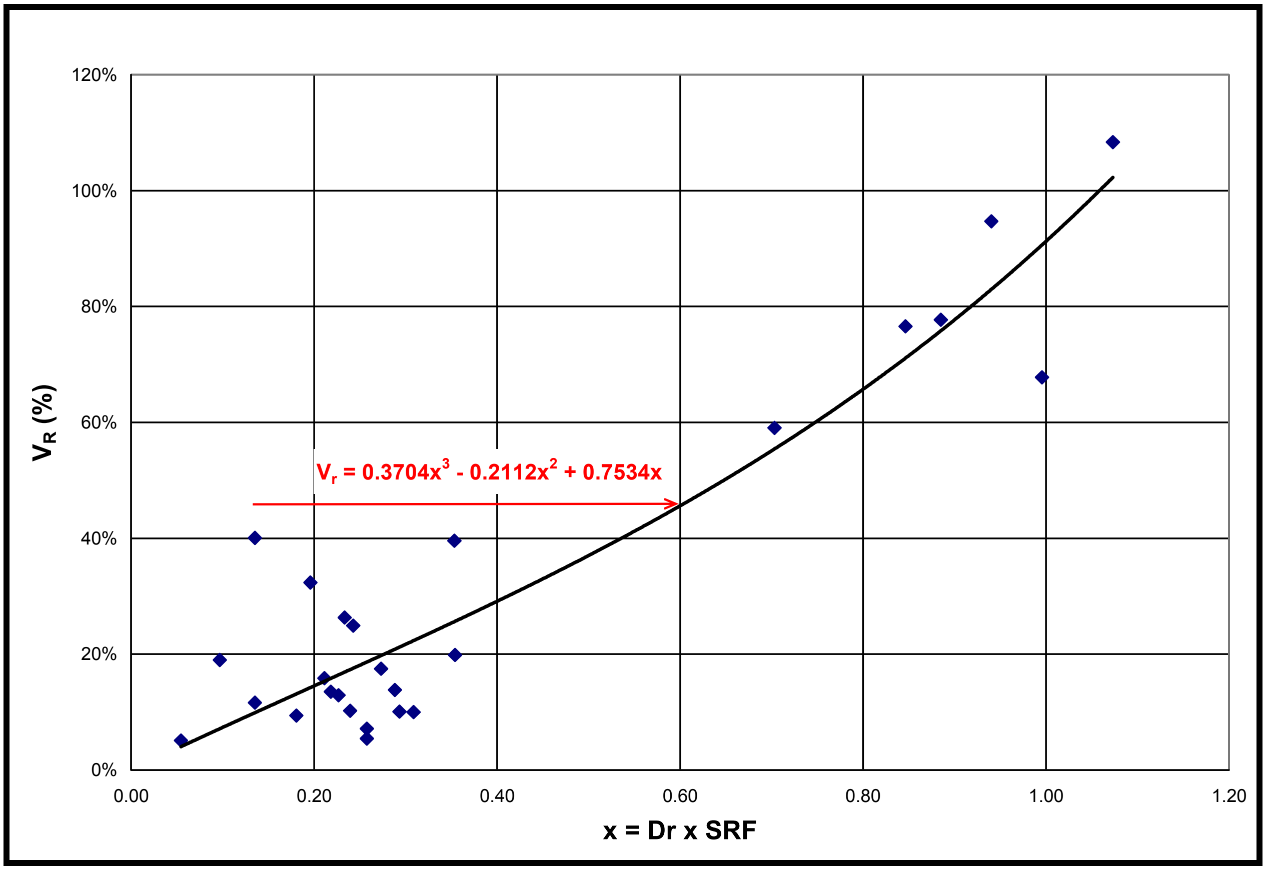


Figure 60. Empirical tidal inlet bar channel shoaling relationship.

The empirical shoaling curve shown in Figure 60 was used to estimate monthly shoaling rates and channel depths in the inlet bar channel at the end of each month over a four-year period. The shoaling analysis assumed that channel construction would be complete at the end of April of Year 1 with shoaling beginning during the month of May of Year 1. As noted above, the empirical shoaling data and the associated empirical shoaling curve are based on average depths in the channel relative to mean tide level. For New River Inlet, mean tide level is about 2.0 feet above mean low water (MLW).

In terms of navigation interest, the minimum depth in the channel, termed the controlling depth, determines the draft of the vessel that can safely use the channel. Due to the variability in the manner in which inlet channels shoal, there is a difference between the average depth and the controlling depth. For the 11 sets of surveys of New River Inlet made between March 2002 and July 2003, the difference between the average depth in the channel and the controlling depths averaged 2.8 feet as shown in Figure 61. That is, if the average depth of the channel from the gorge to the outer edge of the ebb tide delta was 8 feet below MLW, the controlling depth in the channel was 5.2 feet MLW.

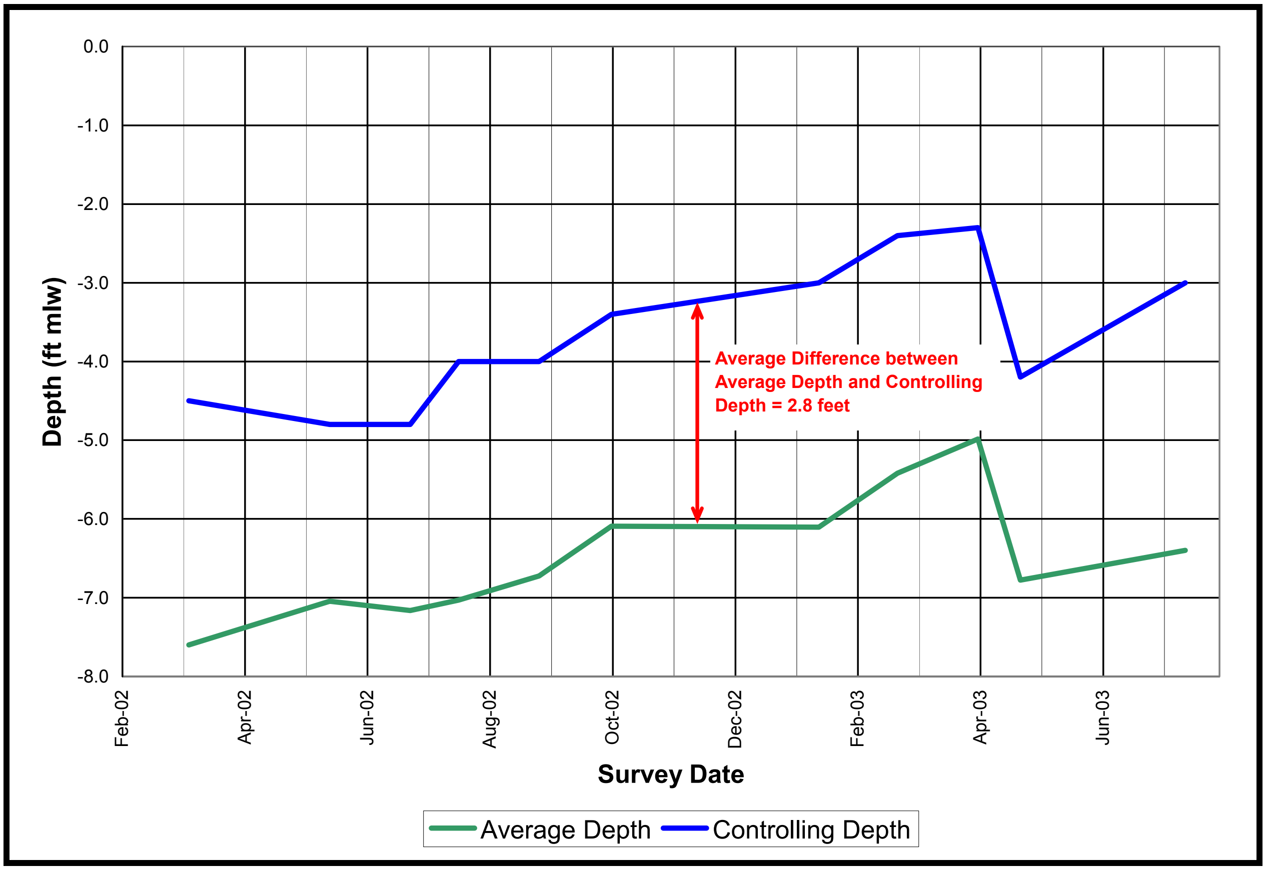


Figure 61. Average and controlling depths, New River Inlet ocean bar channel (March 2002 to July 2003.

Computed average depths and controlling depths that would exist in the preliminary channel over the 4-year analysis period are shown in Figure 62. Based on this analysis, controlling depths in the channel would decrease to less than 6-feet MLW 20 months following construction whereas the average depth of the channel would remain deeper than 6 feet MLW for approximately 38 months. The theoretical volume of material that would shoal the new channel during the 4 year analysis period, assuming no maintenance dredging is performed, is given in Table 10.

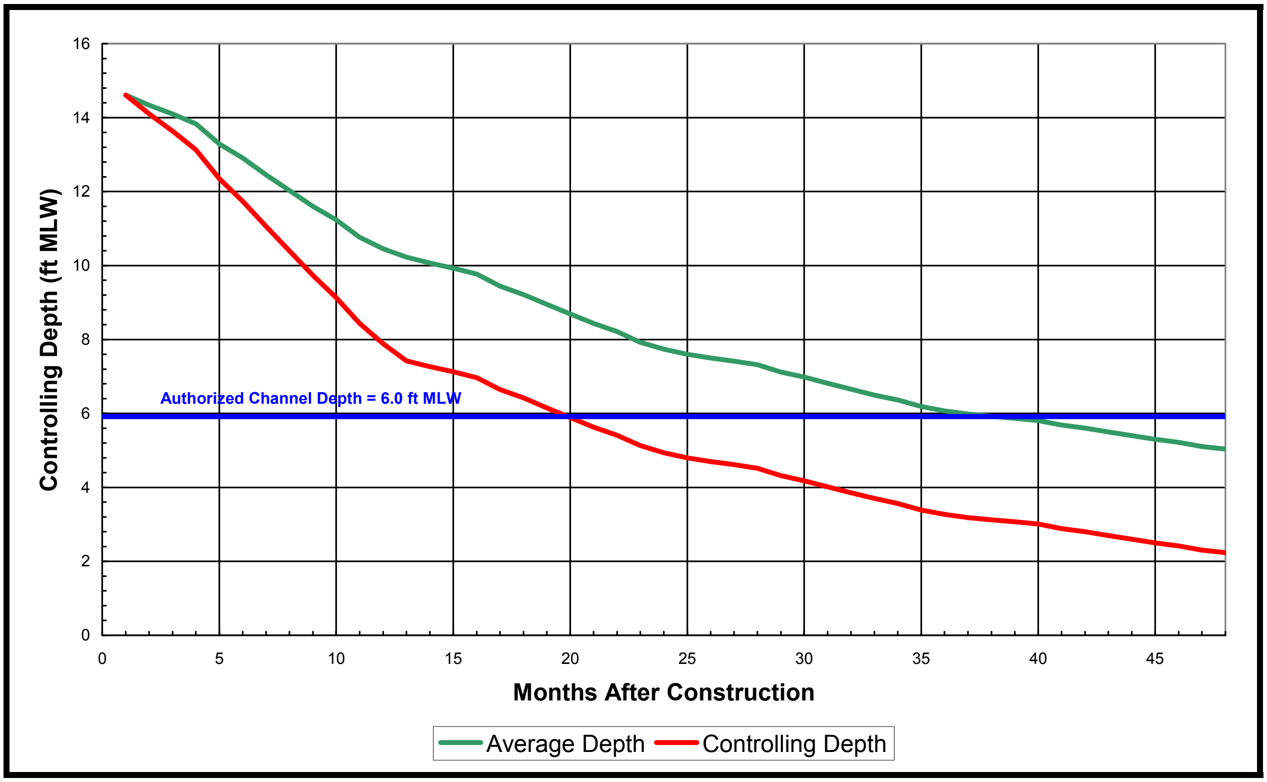


Figure 62. Predicted average and controlling depths in the new ocean bar channel of New River Inlet following construction.

Table 10. Predicted Shoaling in New Channel Without Corps of Engineers Maintenance Dredging.

Year Following Construction	Shoal Volume (cubic yards)
1	286,000
2	171,000
3	105,000
4	65,000
4-year total	627,000

Over the 4-year analysis period, the predicted volume of shoaling in the new bar channel in the absence of any maintenance dredging by the Corps of Engineers; was equal to 627,000 cubic yards or about 157,000 cubic yards/year. The predicted 4-year shoal volume is slightly less than the volume of material that would be removed during initial construction. The Corps of Engineers would presumably renew its normal maintenance dredging activities once controlling depths become less than 6 feet below MLW or in about 20 months following initial channel construction. Due to the nature of the Corps' channel maintenance activities (side cast dredging), the volume of material removed during periodic repositioning and realignment of the new channel should not be significantly impacted.

The predicted volume of shoaling over the 4-year period is about 99% of the initial construction volume and obviously exceeds the 85% shoaling threshold which would trigger channel maintenance. However, due to the time associated with evaluating the channel performance and contracting for channel maintenance, maintenance of the channel would likely not occur until year 4 following initial construction. If the channel tended to meander outside the 500-foot preferred channel corridor prior to shoaling reaching the 85% threshold, channel maintenance could be required sooner. However, based on the estimated shoaling rate and allowing time for channel evaluations and contracting, maintenance to restore and/or maintain the preferred channel position and alignment, maintenance of the channel will be assumed to occur every four years.

IMPACTS OF INLET MANAGEMENT PLAN

Ebb Tide Delta Reconfiguration

Repositioning of the bar channel to a more central position between North Topsail Beach and Onslow Beach and along an alignment essentially perpendicular to the adjacent shorelines should result in a reconfiguration of the ebb tide delta similar to that shown in Figure 63. The white-dashed lines in Figure 63 follow the general outline of the ebb tide delta shown on the October 2003 Corps of Engineers aerial photo while the yellow-dashed lines are schematics of the reshaping of the ebb tide delta that could possibly occur following the relocation of the channel. The position and alignment of the new channel would be similar to that which existed in January 1988 (Figure 39), accordingly, the shape of the reconfigured ebb tide delta was patterned after the shape of the January 1988 ebb tide delta.

Major changes in the ebb tide delta should include the enlargement of the portion of the ebb tide delta lying off the north end of North Topsail Beach and the onshore movement of ebb tide delta material on to the southwest end of Onslow Beach as the portion of the delta northeast of the inlet collapses following the concentration of ebb and flood tidal currents into the new channel. The potential for the onshore transport of some of the ebb tide delta material on the northeast side of the inlet is supported by the results of the numerical model study discussed above.

Shoreline Recovery – North Topsail Beach

The restructuring of the ebb tide delta on the southwest side of the inlet should be accompanied by the reformation of the seaward bulge in the shoreline on the northeast tip of North Topsail Beach due to the elimination of marginal flood channels and the possible buildup of a linear shoal perpendicular to the shoreline similar to that present on the January 1988 photo (Figure 39). During the period 1984 to 2003, the shorelines in the vicinity of stations 1140+00, 1150+00, and 1160+00 receded averages of 110, 180, and 220 feet, respectively. The repositioned bar channel should result in comparable shoreline recoveries over some period of time. Predictions of the actual time for the shoreline between stations 1140+00 and 1160+00 to respond to the new channel cannot be made with a high degree of certainty; however, significant accretion should occur within 5 years with full recovery occurring within 15 years following the channel relocation.

The recovery of the shoreline on the north end of North Topsail Beach will not depend entirely on the impacts of the new bar channel since the shoreline management plan for North Topsail Beach also includes beach nourishment (discussed below). In the absence of the inlet management plan, economical maintenance of a beach fill on the extreme north end of North Topsail Beach would be problematic due to inordinately high periodic nourishment requirements. With the predicted recovery of the shoreline on the north end (110 feet to 220 feet); periodic nourishment requirements should be reduced to manageable and economic levels.

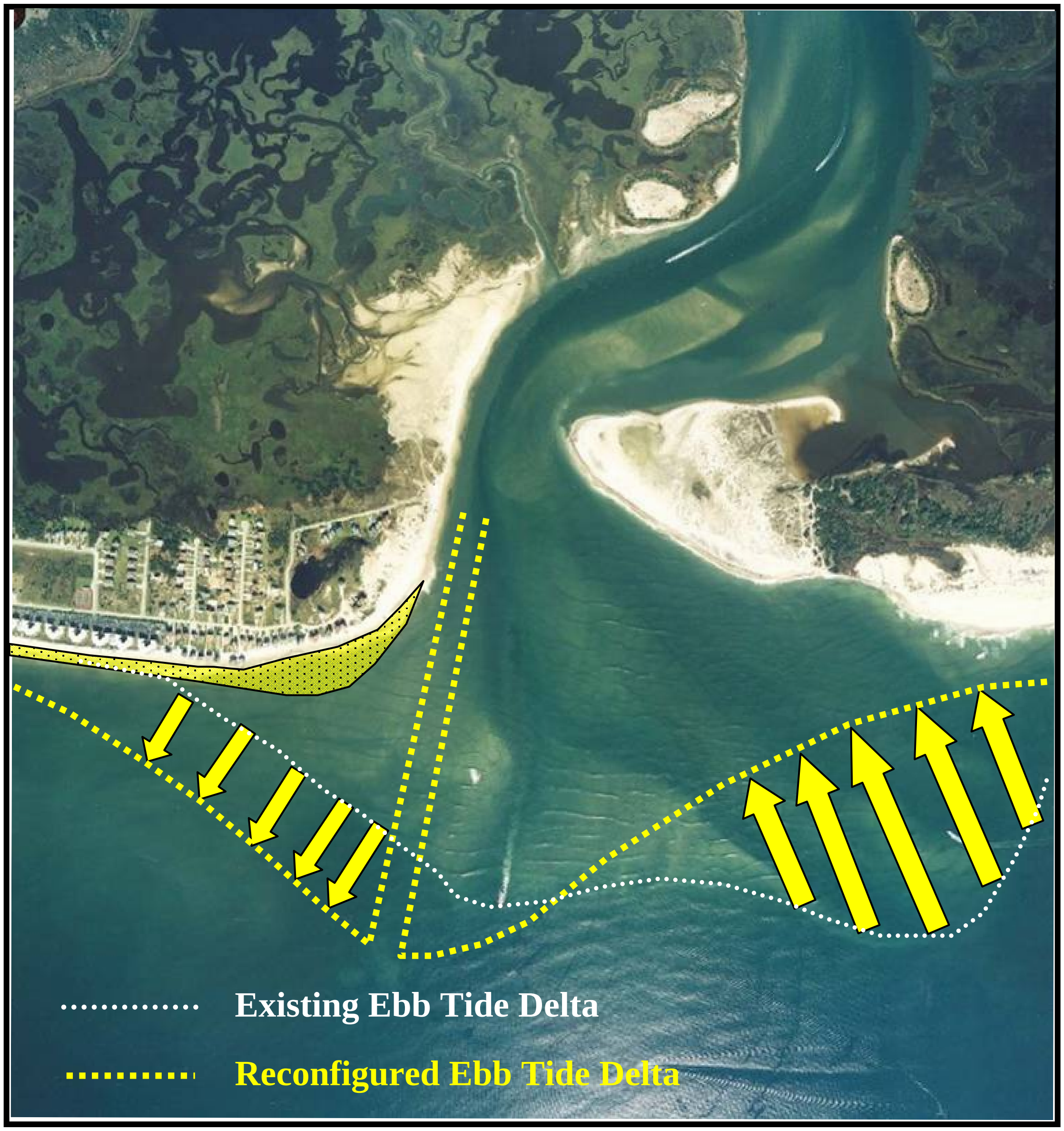


Figure 63. Schematic of Ebb Tide Delta Reconfiguration (Oct 03 Photo).

OCEAN SHORELINE PLAN FORMULATION – NORTHERN 7.25 MILES

Introduction

Construction of a beach fill along the northern 7.25 miles of the Town's shoreline would provide storm protection for homes and infrastructure and protect the Town's tax base. A properly maintained beach fill reduces damages due to shoreline erosion and storm impacts.

Three beach fill design alternatives, designated as: (1) Berm Plan; (2) 14-foot Dune Plan; and (3) 19-foot Dune Plan, were evaluated. The damages that would occur with these three plans in place were compared to damages likely to occur under the No Action Alternative. An analysis of the economic impact of the No Action Alternative and the level of damage prevention that would be afforded by the three beach fill options follows.

No Action Alternative

The No Action Alternative assumes the Town of North Topsail Beach and its property owners would continue to respond to erosion threats and storm damages over the next 30 years using sand bags to provide temporary protection to threatened structures and infrastructure and relocate or demolish threatened buildings and infrastructure once the sand bag permits expire. Other measures, such as the disposal of navigation maintenance material on portions of the North Topsail Beach shoreline by the Corps of Engineers and occasional sand pushing by the Town to rebuild damaged dune lines, would also continue. These latter two actions are deemed to have minor effects on the protective value of the existing beach.

The economic impact of the No Action Alternative includes an assessment of: (a) costs for installing temporary sand bags to protect threatened structures, (b) cost for relocating and/or demolishing threatened structures, and (c) potential storm damages to existing structures and infrastructure. These types of economic impacts are comparable to the economic impacts used by the Corps of Engineers in evaluating Federal shore protection projects. The assessment of the No Action Alternative also includes estimated reductions in ad valorem tax revenues for both the Town and County, loss in room occupancy taxes due to reductions in rental income, and losses in State and local sales taxes resulting from a reduction in household spending that would accompany the loss of permanent residences and rental property due to demolition. These latter economic impacts are considered "local" impacts by the Corps of Engineers and are not included in its economic evaluations for feasibility of a Federal project. However, these impacts directly affect the local economy and are of prime interest to the Town and County.

Methodology

The 7.25 mile shoreline located between the southern boundary of the CBRS (station 785+00) and New River Inlet was divided into thirty-eight (38) 1,000-foot shoreline reaches. The middle of each 1,000-foot reach corresponds to the baseline station, e.g., Reach 80 corresponds to a 1,000-foot reach centered on baseline station 800+00 (Figure 64). Structures within each reach were located relative to the existing shoreline.

The northern area of North Topsail Beach was divided into two sections (Central and North) based on the predominate type of development within each section. The Central Section, which extends from baseline station 785+00 to 950+00, consists primarily of single family residences while the North Section, located between baseline station 950+00 and 1160+00, has predominately multi-family units (Figure 64).

Assumptions used for the No Action Alternative were:

(1) Shoreline erosion will continue at the same rate as experienced during the period from 1983 to 2002. For purposes of this analysis, the "shoreline" was defined as the +7 foot NAVD contour.

(2) When a structure becomes threatened, i.e., when the shoreline encroaches within 20 feet of the structures foundation, or in the case of a road, within 20 feet of the right-of-way, a temporary sandbag revetment would be installed to protect the structure. For structures with less than 5,000 square feet of floor space, the permit period for the temporary sand bag structure is 2 years. The sand bag permit period for structures with a floor space equal to or greater than 5,000 square feet, including roads, is 5 years.

(3) At the end of the sandbag permit period, the structure would be relocated to another lot, moved landward on the existing lot, or demolished.

(4) While relocation to another location within the Town limits of North Topsail Beach may be possible, the cost associated with relocation would be too high for some property owners. Therefore, approximately one-half of the threatened structures with a total floor space of less than 5,000 square feet were assumed to be relocated with the other half demolished and the lot abandoned.

(5) Relocation could occur either on the existing lot, providing the lot has enough depth, or to a vacant lot located near the structure. Relocation of the threatened structure to a new lot would remove the value of the existing lot from the Town and County tax base but would preserve the tax value of the structure.

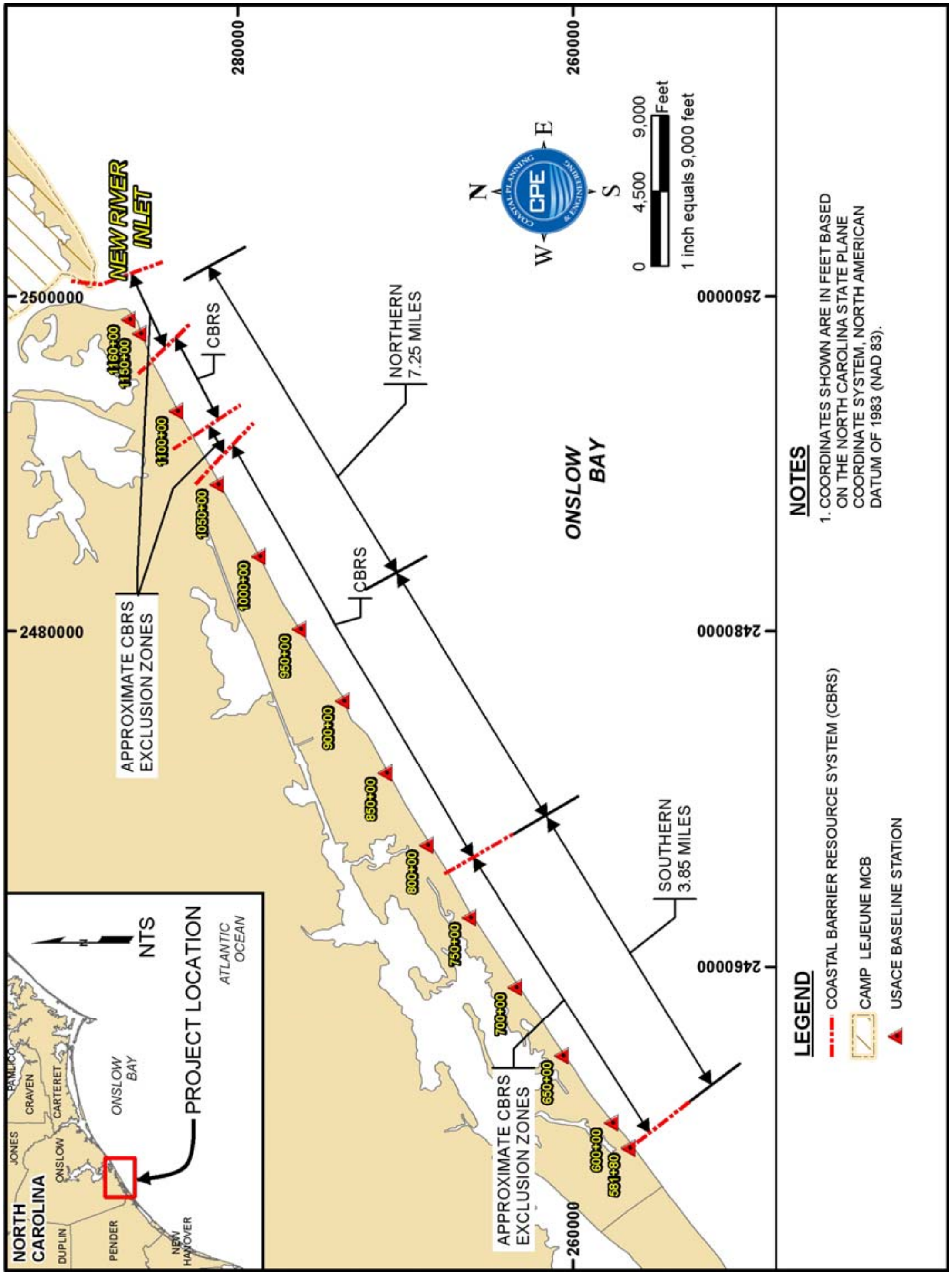


Figure 64. Baseline stations (center of 1000-foot shoreline reaches) and location of Central and North Sections.

(6) The ad valorem taxes on developed and undeveloped parcels were based on the 2000 tax value. The present Town tax rate, which is based on the 2000

evaluation, is $0.45/$100 and the County tax rate is $0.67/$100. Even though the appraised value of properties has changed substantially with the 2006 reappraisal, the inherent assumption is the Town and County operating expenses, and hence their need for tax revenue, will remain essentially the same over time.

(7) The cost of relocation would be attributed to the individual property owner. Included in the relocation costs are; the cost of a new lot, installation of new foundation piles, installation of new utilities (water, sewer, electric, telephone, HVAC), the actual cost of moving the structure, and clean-up of the abandoned lot.

(8) Vacant land in the vicinity of the larger multi-family and multi-story structures (>5,000 square feet of floor space) is not sufficient to accommodate moving the structures, therefore, the larger structures were assumed to be demolished once the sandbag permits expire.

(9) Demolition of the structure would result in a reduction of the Town and County tax base equal to the combined tax value of the structure and lot.

(10) The tax revenues lost to both the Town and County from relocations or abandonment would carry over from year-to-year, i.e., the lost tax revenues would be cumulative dating from the time the structures are relocated or abandoned.

(11) Demolition costs, which would be the responsibility of the individual property owners, include the cost to disconnect the utilities, demolish the structure, and dispose the buildings debris.

(12) A portion of New River Inlet Road, located in Reach 107 (baseline station 1070+00), would become threatened in year 10 from the present and with additional sections, located in Reaches 101 to 108 (baseline stations 1010+00 to 1080+00), being threatened over the next 10 years (years 10 to 20 from present). Sandbag revetments would be incrementally installed during this 10 year period to provide temporary protection to 4,000 feet of road that would become threatened prior to its relocation. The temporary sandbag revetments would allow time to plan and design the relocation of the road and acquire the necessary lands for the new right-of-way. Relocation of the road would occur in year 20. The permit period for some of the sandbag revetments protecting the road were assumed to be extended beyond 5 years by appealing to the Coastal Resources Commission.

(13) All of the structures situated on lots needed for the new right-of-way would be moved to a vacant lot within the Town limits of North Topsail Beach. Vacant lots within the new right-of-way as well as the occupied lots would be purchased for the right-of-way and thus removed from the Town and County tax base. The purchase cost of the lots was based on their fair market value.

(14) The right-of-way costs for the new road would be the responsibility of the Town of North Topsail Beach.

(15) The present worth of all future actions and the equivalent average annual cost were based on a 6% discount rate and a 30-year amortization period.

The thirty-eight 1,000-foot reaches contain 1,158 housing units. Housing units include single family homes as well as multi-family structures such as the St. Moritz (Reach 82), Villa Capriani (Reach 97), Topsail Villas (Reach 98), Topsail Dunes (Reach 110), Ship Watch Villas (Reach 111), St. Regis Resort (Reach 112), and Topsail Reefs (Reaches 114-115). The North Topsail Beach tax database lists approximately 500 housing units as rental properties.

Long-Term Erosion Impacts – No Action Alternative

Relocation and Abandon (Demolish) Costs. The economic impact of relocating threatened structures included costs that would be borne by the property owners. Relocation costs that would be the responsibility of the individual property owner include cost for: (a) installation of a temporary sandbag revetment, (b) fees and permits, (c) abandoning and reinstalling new utilities (water, sewer, electric, telephone, HVAC), (d) removing old piles from the existing lot, (e) installation of new piles on the new lot, (f) the actual cost of moving the structure and placing it on its new foundation piles, and (g) cost for a new lot. The cost for the temporary sandbag revetment was computed at a unit cost of $250/lineal foot of ocean front while the cost of moving the structure to the new lot and placing it on the new pile foundation was based on a unit cost of $37/square foot of floor space (Means, 2000). A lump-sum of $42,000/structure was applied to cover the cost for fees and permits, utility work, new pile installation, and removal of the old piles. Based on the 2006 reappraisal of property values in North Topsail Beach, the cost of a new lot would average $800,000.

Demolition of threatened buildings would be preceded by the installation of temporary sand bags. The cost for the sand bags and demolition and disposal of the abandoned structure would be the responsibility of the individual property owner. Demolition cost for structures was determined from information contained in RS Means "Building Construction Cost Data" (Means, 2000). Building demolition would occur at a rate of 14,800 cubic feet per day with a crew cost of $4,500 per day. Disposal of the building debris would cost $20 per cubic yard plus a $5/cubic yard tipping fee at the local landfill. The volume of each building to be demolished was determined from its floor space.

The present worth of the cost of installing temporary sand bags and relocating or demolishing a threatened building was determined for the year in which the action would be required. The average annual equivalent cost of the action was computed using the 6% discount rate and an amortization period of 30 years. The equivalent average annual costs for sand bags, relocating threatened structures, and demolition of threatened structures are summarized for each reach in Table 12. Economic impacts on two Topsail Reefs condominium units located in Reach 115 are reported separately as Reach "115 Topsail Reefs" while Reach 115 includes development located north of Topsail Reefs.

Storm Damage Potential – No Action Alternative

The potential level of storm damage for under the No Action Alternative was evaluated by applying a beach profile storm response model known as SBEACH which was developed by the Corps of Engineers (USACE, 1989a). SBEACH was run using a suite of 37 historic storms that affected the study area over the 107-year period from 1893 to 1999. Characteristics of the 37 historic storms were provided by the Wilmington District Corps of Engineers. Four profiles were selected for evaluation, namely, 850+00, 940+00, 1030+00, and 1110+00. Figures 65A and 65B show typical SBEACH results obtained for the existing condition for profiles 850+00 (Central Section) and 1030+00 (North Section) respectively for Hurricane Fran (September 6, 1996).

The potential for damage to buildings associated with the SBEACH results are based on the distance from the position of the 0-foot NAVD contour on the existing profile to the landward point where the post-storm profile is 0.5 foot lower than the existing profile. This area is identified as the storm impact zone in Figures 65a and 65B. While the lowering of the profile by 0.5 foot would not necessarily result in damage to buildings, the assumption associated with the SBEACH results is that the location of the 0.5-foot erosion point relative to buildings provides an indication of the severity of the storm impact (waves and storm surge) on that building. If the 0.5-foot erosion point remains seaward of a building, no damage would be assigned to that building. However, if the 0.5-foot erosion point is landward of the seaward face of the building, the level of damage would depend on the distance from the seaward face of the building to the 0.5-foot erosion point. For example, if the erosion point moves mid-way through the building, the level of damage assigned to that building would be 50%.

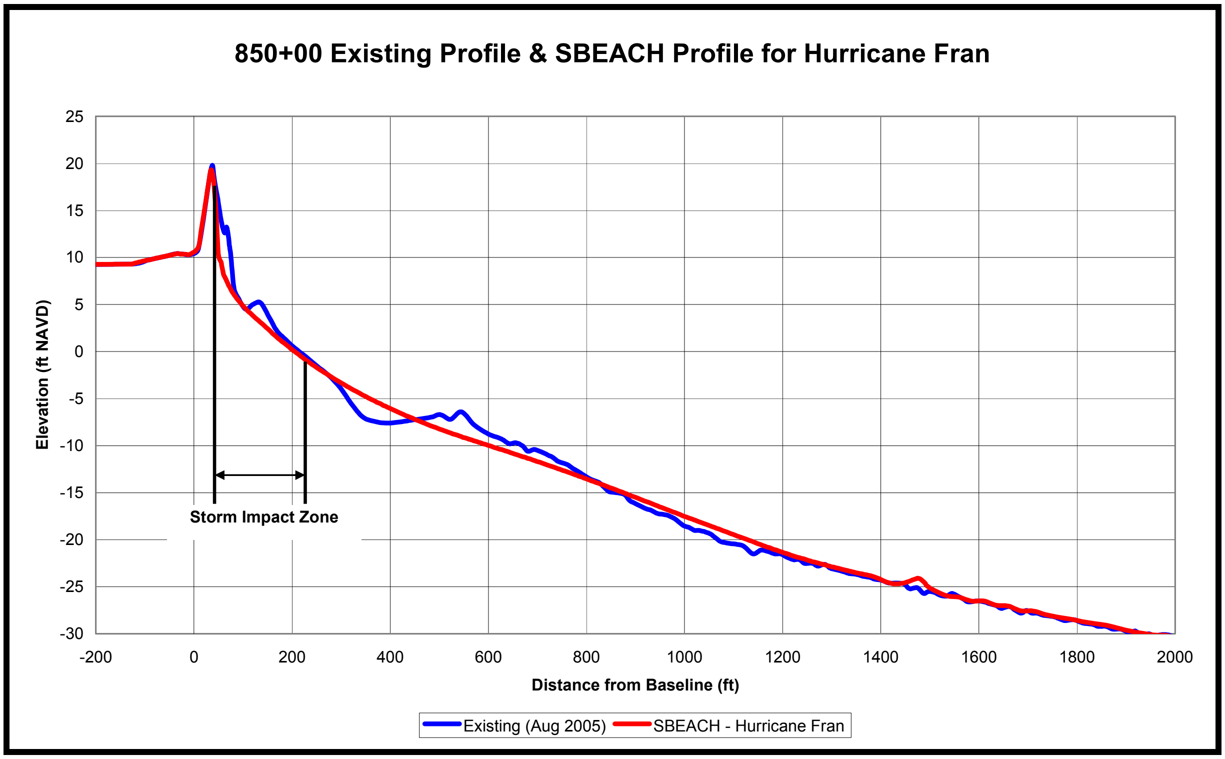


Figure 65A. SBEACH results, No Action Alternative, Profile 850+00, Hurricane Fran (9/6/96).

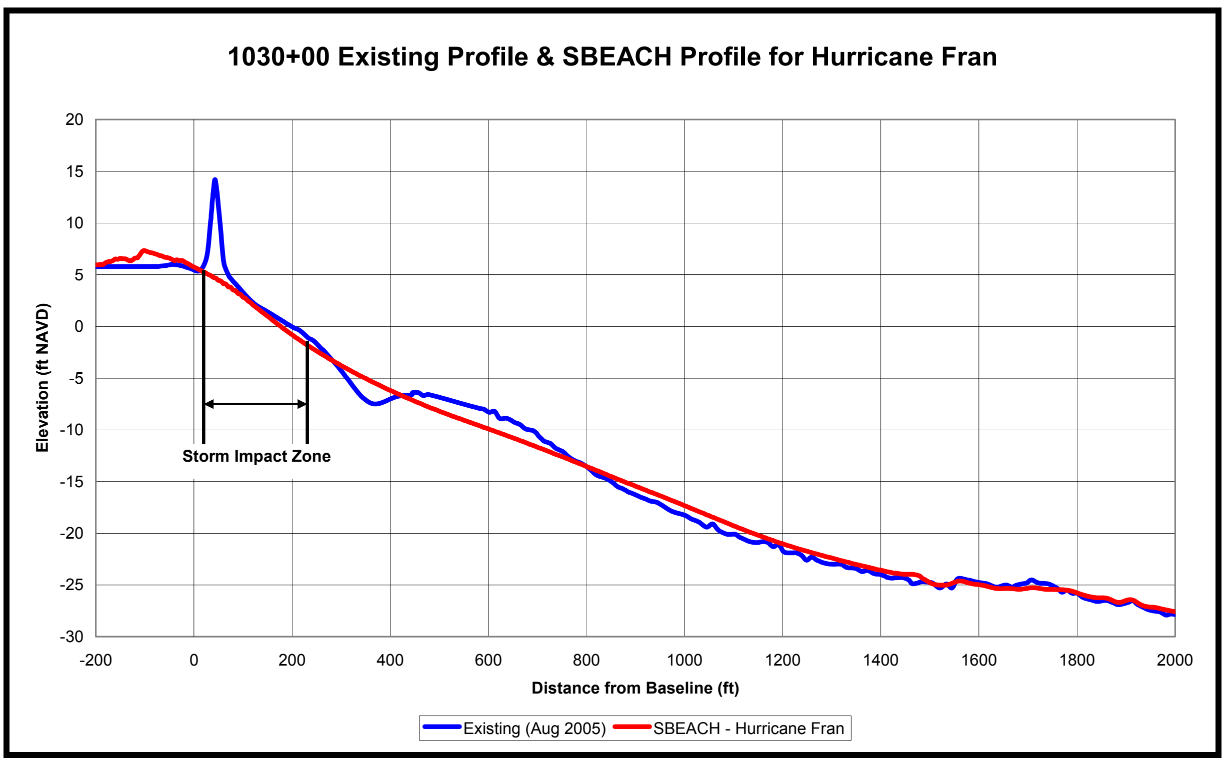


Figure 65B. SBEACH results, No Action Alternative, Profile 1030+00, Hurricane Fran (9/6/96).

SBEACH was applied to the four beach profiles using all 37 storms. The distance from the 0-foot NAVD contour on the existing profiles to the 0.5-foot erosion point (storm impact distance) was tabulated for each profile and the storm impact distances ranked from 1 to 37 with the greatest storm impact distance ranked 1. The return interval (in years) of each storm impact distance was determined from the following relationship:

$$\text{Return Interval (years)} = (n+1)/m$$

where: n = number of years in the record = 107 years
m = rank of storm impact distance with greatest distance ranked 1.

The results of the SBEACH analysis for the four profiles under existing conditions were used to develop storm impact distances with return intervals of 5, 10, 15, 20, and 25 years applicable to various sections of North Topsail Beach. The storm impact distances for the No Action Alternative are given in Table 11.

Table 11. No Action Alternative. Summary of economic impacts due to long-term erosion and storms.

Reach	Number Structures Relocated to New Lot	Number Structures moved back on Existing Lot	Number Structures Demolished	Average Annual Cost Sand Bags	Average Annual Cost Relocation	Average Annual Cost Demolition	Average Annual Storm Damages	Total Damages
79	0	3	0	$1,600	$16,900	$0	$38,300	$56,800
80	0	2	4	$1,900	$4,500	$1,700	$217,900	$226,000
81	0	2	0	$0	$0	$0	$13,600	$13,600
82 (St. Moritz)	0	0	3	$4,600	$0	$13,500	$145,000	$163,100
83	3	0	0	$1,700	$118,100	$0	$128,200	$248,000
84	3	0	3	$1,300	$34,300	$2,100	$108,900	$146,600
85	1	1	6	$3,200	$29,700	$6,700	$369,400	$409,000
86	5	1	8	$5,000	$132,700	$5,400	$1,129,400	$1,272,500
87	0	0	4	$1,900	$0	$4,100	$323,400	$329,400
88	3	0	2	$2,100	$89,200	$2,800	$513,200	$607,300
89	6	0	0	$2,600	$184,300	$0	$380,400	$567,300
90	0	0	0	$0	$0	$0	$34,600	$34,600
91	0	0	0	$0	$0	$0	$0	$0
92	4	0	3	$2,600	$97,800	$2,400	$682,100	$784,900
93	2	1	2	$2,500	$68,600	$1,900	$486,500	$559,500
94	0	0	1	$500	$0	$1,200	$181,000	$182,700
95	1	0	0	$400	$27,000	$0	$109,500	$136,900
Totals for Central Section	**28**	**10**	**36**	**$31,900**	**$803,100**	**$41,800**	**$4,861,400**	**$5,738,200**
96	1	0	2	$1,200	$27,600	$1,700	$93,400	$123,900
97 (Villa Capriani)	3	0	1	$21,200	$171,600	$110,900	$1,290,100	$1,593,800
98 (Topsail Villas)	3	2	3	$8,100	$116,900	$6,100	$230,000	$361,100
99	0	4	0	$1,500	$11,100	$0	$64,600	$77,200
100	1	0	5	$3,900	$23,400	$7,700	$183,600	$218,600
101	1	0	3	$1,200	$117,900	$2,100	$166,500	$287,700
102	5	0	6	$7,700	$274,600	$8,500	$239,200	$530,000
103	0	5	2	$14,400	$178,500	$2,700	$64,500	$260,100
104	2	0	1	$700	$287,200	$1,700	$67,000	$356,600
105	10	0	2	$800	$462,800	$4,900	$95,000	$563,500
106	0	1	1	$15,100	$155,700	$0	$38,100	$208,900
107	6	0	0	$25,600	$272,300	$0	$104,500	$402,400
108	5	0	0	$0	$334,600	$0	$81,800	$416,400
109 (Ship Watch Villas Town Homes)	0	0	1	$28,800	$61,300	$1,400	$679,900	$771,400
110 (Topsail Dunes)	0	0	3	$8,600	$0	$16,000	$3,195,800	$3,220,400
111 (Ship Watch Villas)	0	0	1	$8,200	$0	$0	$1,543,000	$1,551,200
112 (St. Regis)	0	0	0	$0	$0	$0	$2,115,800	$2,115,800
113	0	0	0	$0	$0	$0	$571,600	$571,600
114 Topsail Reefs	0	0	6	$32,000	$0	$86,600	$1,666,200	$1,784,800
115 Topsail Reefs	0	0	2	$10,900	$0	$29,300	$605,300	$645,500
115	12	0	12	$8,300	$558,500	$30,600	$415,000	$1,012,400
116	6	0	10	$8,500	$318,900	$36,200	$251,500	$615,100
Totals for North Section	**55**	**12**	**61**	**$206,700**	**$3,372,900**	**$346,400**	**$13,762,400**	**$17,688,400**
Totals	**83**	**22**	**97**	**238,600**	**4,176,000**	**388,200**	**18,623,800**	**23,426,600**

Distances to the seaward face of each building from the existing 0-foot NAVD contour were measured from a 2005 aerial topographic map of North Topsail Beach developed by Coastal Planning & Engineering, Inc. The depth of each structure, i.e., the distance from the seaward face to the back of the structure, was also measured off the aerial topographic map. This information was used to estimate the level of damage to each structure for the 5 storm impact distance return intervals given in Table 12. For New River Inlet Road, the distance from the 0-foot NAVD contour to the edge of the right-of-way was measured and the damage to the road and associated utilities (water, sewer, electric, telephone & cable TV) based on the position of the 0.5-foot erosion point relative to the right-of-way. The damage associated with each storm impact distance return interval was converted to an average annual damage by multiplying the damage amount by the probability of occurrence of the storm impact distance in any one year (i.e., 20%, 10% 6.7%, 5%, and 4% for the 5, 10, 15, 20 and 25 year return intervals, respectively). The damages associated with the individual return intervals were summed to yield an estimate of the total equivalent average annual storm erosion damages for each reach.

For the No Action Alternative, the equivalent average annual storm damages to each structure were modified based on the probability that the structure would be in place during the 30-year analysis period. As discussed previously, under the No Action Alternative, some structures would be either relocated away from the ocean or demolished as a result of continued shoreline recession. For example, if a structure would be demolished or removed during year 5 of the analysis, potential average annual storm damages to that structure were multiplied by 16.67% (= 5/30) which is the average probability the structure would be in place during the storms.

Sandbag revetments may be installed to provide temporary protection against continued long-term shoreline erosions, however the sandbag structures would not provide any substantial protection during the storms and their impact was ignored in the storm damage assessment. Structure values used in the analysis were based on the 2006 reevaluation. Average annual storm damages for each reach are summarized in Table 12.

Table 12. Return intervals for storm impact distances – No Action Alternative.

Reaches	**Baseline Stations**	**Storm Impact Distances (feet)[1]**				
		Return Intervals (years)				
		5	**10**	**15**	**20**	**25**
79 to 85	785+00 to 855+00	173	199	208	220	230
86 to 90	855+00 to 905+00	180	216	253	268	275
91 to 95	905+00 to 955+00	187	232	298	316	320
96 to 103	955+00 to 1035+00	192	221	255	274	280
104 to 116	1035+00 to 1165+00	200	223	254	293	305

[1] Storm Impact Distance = Distance from 0-ft NAVD on existing profile to the 0.5-foot erosion point on the post-storm profile.

Ad Valorem Tax Revenues

The Town of North Topsail Beach and Onslow County would experience a reduction in their respective tax bases under the No Action Alternative. The reduction in the tax bases would occur from both relocations, where existing lots would be removed from the tax base and from demolition, where both the structure and lot value were assumed to be removed from the tax base. Removal of a structure or parcel from the tax base would continue to impact tax revenues for the balance of the 30-year analysis period following its removal. The number of structures that would be relocated to a new lot, moved back on an existing lot, or demolished; are given for each reach in Table 11. Moving a structure back on an existing lot was assumed to have no impact on its tax value.

An example is presented on how the loss of ad valorem taxes was computed. Demolition of a structure in year 15 of the analysis would impact tax revenues for the remaining 15 years of the analysis period. For a 2000 tax value of $300,000 (land and structure), the loss in the yearly ad valorem tax would be $1,350 for the Town of North Topsail Beach ($0.45/$100) and $2,010 for Onslow County ($0.67/$100). The loss of this yearly ad valorem tax would be cumulative over the remaining 15 years resulting in a total loss of $20,250 for the Town and $31,515 for the County. These cumulative losses were divided by 30 to yield the average annual reduction in ad valorem taxes over the 30-year analysis period associated with the loss of the parcel. For this example, the average annual loss in ad valorem taxes for the Town and County would be $700 and $1,100, respectively (note: values rounded to nearest $100). For the case in which the structure is located to a new lot, the loss in tax revenue was based on the 2000 appraised value of the abandoned lot. Average annual losses in the 2000 tax values and the associated reduction in ad valorem tax revenues in the Central and North Sections are presented in Table 13.

Cumulative losses in tax revenues under the No Action Alternative for the Town of North Topsail Beach and Onslow County over the next 30 years are shown in Figure 66. With the No Action Alternative, annual ad valorem tax revenues for the Town of North Topsail Beach would be reduced by almost $65,000/year by year 6 with losses for the County equal to $96,000/year. Reductions in tax revenues would increase to $112,000 for the Town and $167,000/year for the County by year 16.

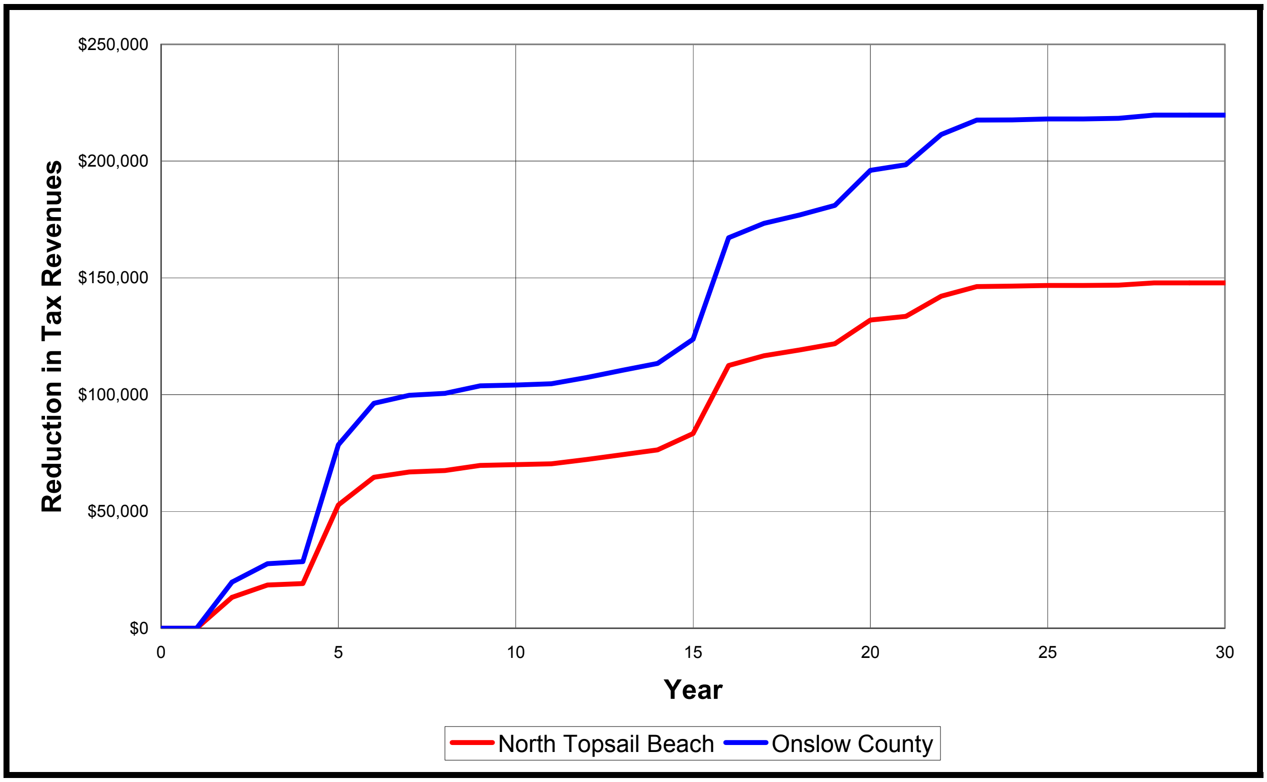


Figure 66. Cumulative reduction in North Topsail Beach and Onslow County ad valorem tax revenues.

Rental and Room Occupancy Tax Losses

Potential rental losses, which would impact room occupancy tax revenues, were determined from the number of cottages and condo units that would have to be demolished over the next 30 years. The room occupancy tax rate is 3% for both Town of North Topsail Beach and Onslow County (total of 6%). Not all of the cottages and condo units that would be demolished over the 30-year analysis period are for rent. Based on property classifications included in the Town's tax database, approximately 50% of the units that would be demolished under the No Action Alternative were assumed to be for rent. The more active rental period covers 18 weeks from the middle of May to the middle of September. Rental rates are highest during the 10-week prime season which runs from mid-June to mid-August with lower rates during the 4 weeks prior to and following the prime season.

The potential rental losses were based on a weighted average weekly rental rate for oceanfront cottages determined from a representative sample obtained from the following two websites:

http://www.treasurerealty.com/rentals/rentalindex.htm
http://www.vamoose.com/topsail-island-vacation-rentals.html

The sample included 88 oceanfront cottages with 3 and 6 bedrooms and included rates during the prime season and mid season. Rental rates for the condo units (Villa Capriani, Topsail Dunes, etc) were also sampled. Based on the samples, the following weighted average weekly rental rates were used to determine the potential rental losses over the next 30 years:

Oceanfront Cottages	$3,200/week
Villa Capriani	$1,400/week
Topsail Dunes, Ship Watch Villas, & Topsail Villas	$ 900/week
Topsail Reefs	$ 700/week

Potential rental losses were based on an 80% occupancy rate during the 18-week rental season. For oceanfront cottages that would be relocated to a non-oceanfront lot, rental income would be reduced by an average of $1,000/week. This reduction was based on a comparison of rental rates between oceanfront and non-oceanfront cottages obtained from the same two websites listed above.

Losses in rental income would be cumulative over the period following the demolition of the unit. For example, demolition of an oceanfront rental cottage in year 20 would result in the loss of rental income over the next 10 years. For an 80% occupancy rate, the cumulative losses over the 10 year period would be $460,800. The present worth of the losses in rental income were computed for the year in which the rental property would be demolished and the present worth of the rental losses converted to an equivalent average annual loss using the 6% discount rate and an amortization period of 30 years. In this example, the equivalent average annual reduction in rental income would be $11,300. The total average annual loss in rental income over the 30-year analysis period for all reaches within the project area totaled over $4.2 million. The average annual reduction in room occupancy taxes associated with this reduction in rental income were determined by multiplying the average annual reduction in rental income by 6%, the combined room occupancy tax rate for the Town of North Topsail Beach and Onslow County. Average annual losses in rental income and the associated room occupancy tax for the Central and North Section are given in Table 13.

Local and State Sales Tax

A total of 97 housing units would be demolished over the next 30 years if the ocean shoreline continues to erode at the average rates determined between 1983 and 2002. Year-round occupancy rates for non-rental properties was assumed to be 70% with the year-round occupancy rate for rental properties equal to 30%. The loss of these households would have a direct impact on the local economy consisting of a reduction in household spending and a loss of the associated State and local sales taxes. The total sales tax in Onslow County is 7% which includes a local share of 2.5% and a State share of 4.5%.

A survey conducted by the American Express Company[1] found household spending for items such as utilities, groceries, gasoline, healthcare, fast food, education, home furnishings, and drug store items (health and beauty aids) totaled $17,300 in 1999. These are items that would be purchased locally and have an impact on the local economy. The cost for these household expenses has historically increased by 5 percent per year so that the equivalent rate in 2006 would be approximately $24,000/year per household.

Reductions in household spending and the associated average annual loss in sales taxes were computed in the same manner as the reduction in rental income. Average annual reductions in household spending and the associated reduction in local and State sales taxes in the Central and North Sections are summarized in Table 13.

Table 13. Average annual reduction in 2000 tax values, ad valorem taxes, rental income, accommodation taxes, household spending, and sales taxes – No Action Alternative

Average Annual Reduction in:	Central Section	North Section	Total
2000 Tax Values	$19,238,000	$46,822,000	$66,060,000
Town Ad Valorem Taxes	$31,700	$115,500	$147,200
County Ad Valorem Taxes	$46,900	$172,000	$218,900
Total Ad Valorem Taxes	**$78,600**	**$287,500**	**$366,100**
Rental Income	$529,500	$3,709,800	$4,239,300
Accommodation Tax	**$31,800**	**$222,800**	**$254,600**
Household Spending	$207,000	$5,437,600	$5,644,600
Local Sales Tax	$5,300	$135,800	$141,100
State Sales Tax	$9,300	$244,800	$254,100
Total Sales Tax	**$14,600**	**$380,600**	**$395,200**

[1](http://home3.americanexpress.com/corp/latestnews/everyday_spend.asp)

Beach Fill Options

Berm Plan. The feasibility report prepared for the Town of North Topsail Beach (CPE, September 2004) recommended a basic beach fill design consisting of 50 cubic yards/lineal foot of beach for the Central Section (baseline stations 785+00 to 950+00) and 75 cubic yards/lineal foot of beach for the North Section (950+00 to 1150+00). At the time of construction, 4-years of advanced nourishment would be included in order to maintain the design sections between periodic nourishment operations. Stations 1080+00 through 1160+00 are directly impacted by the New River Inlet and as a result require additional advanced nourishment. In order to counter act the inlet induced erosion an additional 12.1 cubic yards/lineal foot needs to be added to stations 1080+00 through 1140+00, 17.2 cubic yards/lineal feet to station 1150+00, and 28 cubic yards/lineal foot to station 1160+00. The fills would be constructed in the form of a horizontal beach berm at elevation +6.0 feet NAVD. Typical sections of the berm plan are shown in Figures 67A and 67B. The width of the construction berm would depend on the actual foreshore slope the fill material assumes during construction. Based on past experience with beach fills in North Carolina, the foreshore slope is assumed to be 1V:15H (1 Vertical:15 Horizontal).

Following the initial placement of the material, the beach fill will undergo slope adjustments that will move some of the material seaward to a point of intercept. This post-construction adjustment will reduce the width of the fill close to the design widths of 50 and 75 feet. An analysis of the equilibrium toe of the fill is presented later following the selection of the recommended beach fill option.

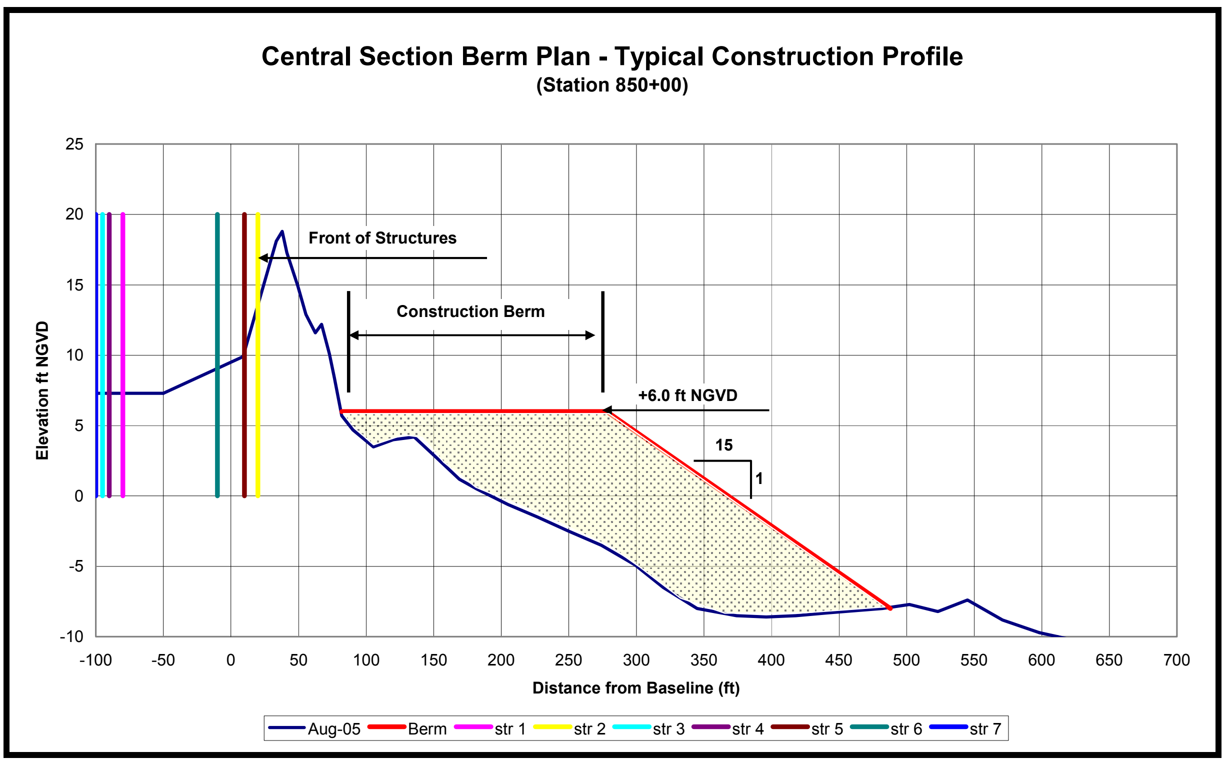


Figure 67A. Typical construction profile, Central Section Berm Plan (Station 850+00).

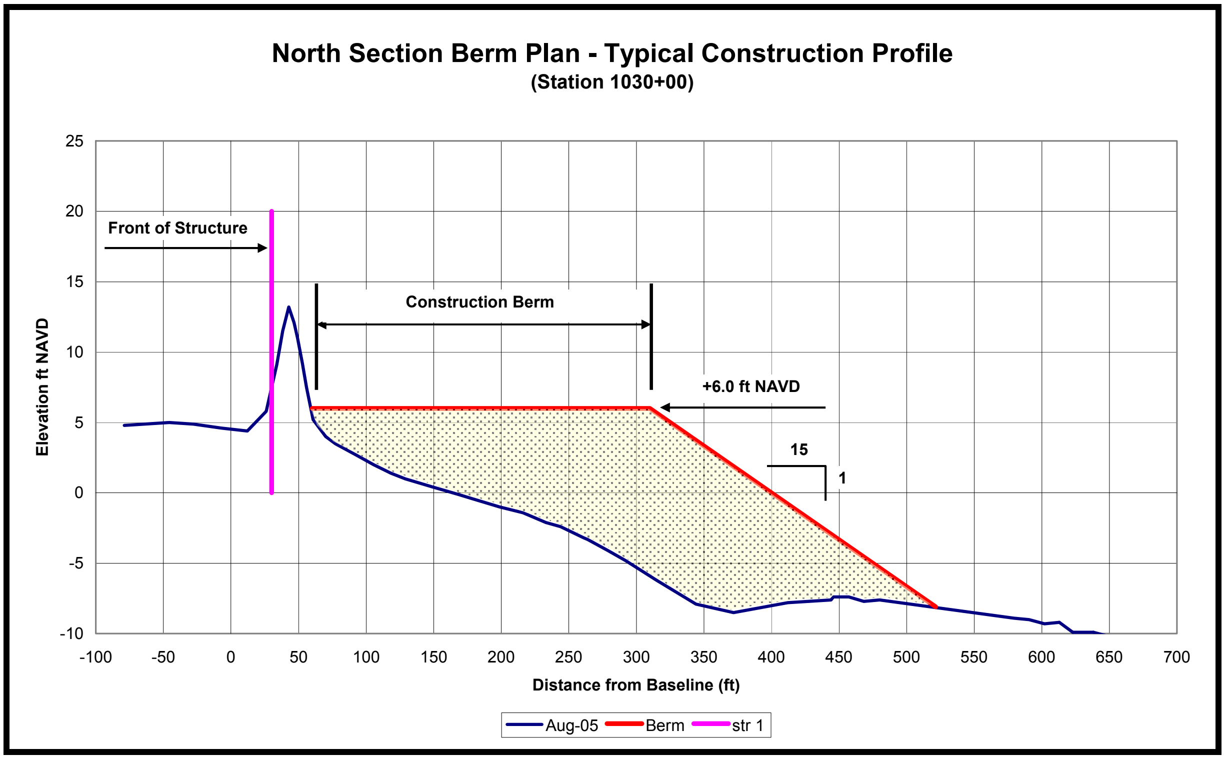


Figure 67B. Typical construction profile, North Section Berm Plan (Station 1030+00).

14-foot Dune Plan. A dune with a crest elevation +14.0 feet NAVD would be included in the fill section. The crest of the dune will tie into the existing dune system or in areas where the existing dune elevation is less than +14 feet NAVD; the dune would be constructed with a crest width of 25 feet. The seaward face of the dune would slope 1V:5H down to a +6.0-foot NAVD berm and where applicable, the landward slope of the dune would be 1V:3H. The initial construction of the 14-foot Dune Plan would also include 4-years of advanced nourishment. Typical construction profiles for the 14-foot Dune Plan are shown in Figures 68 and 69 for the Central (Station 850+00) and North Sections (Station 1030+00), respectively.

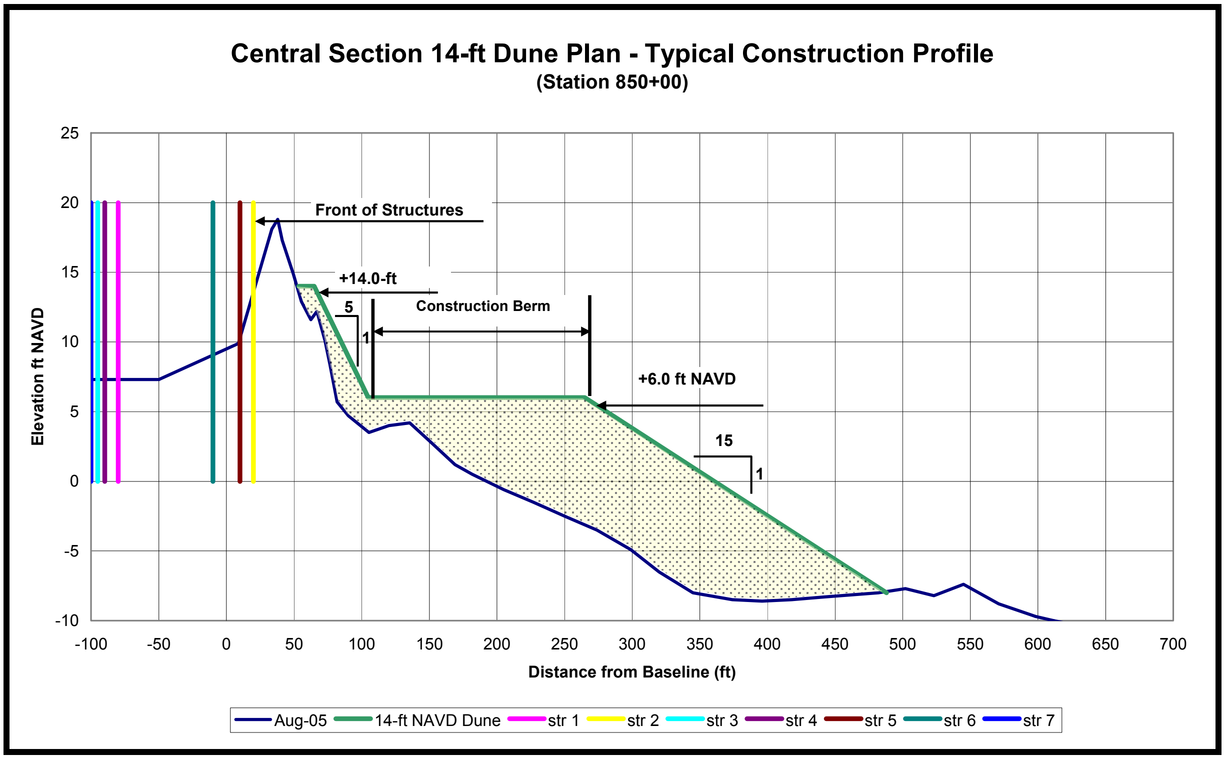


Figure 68. Typical construction profile, Central Section 14-foot Dune Plan (Station 850+00).

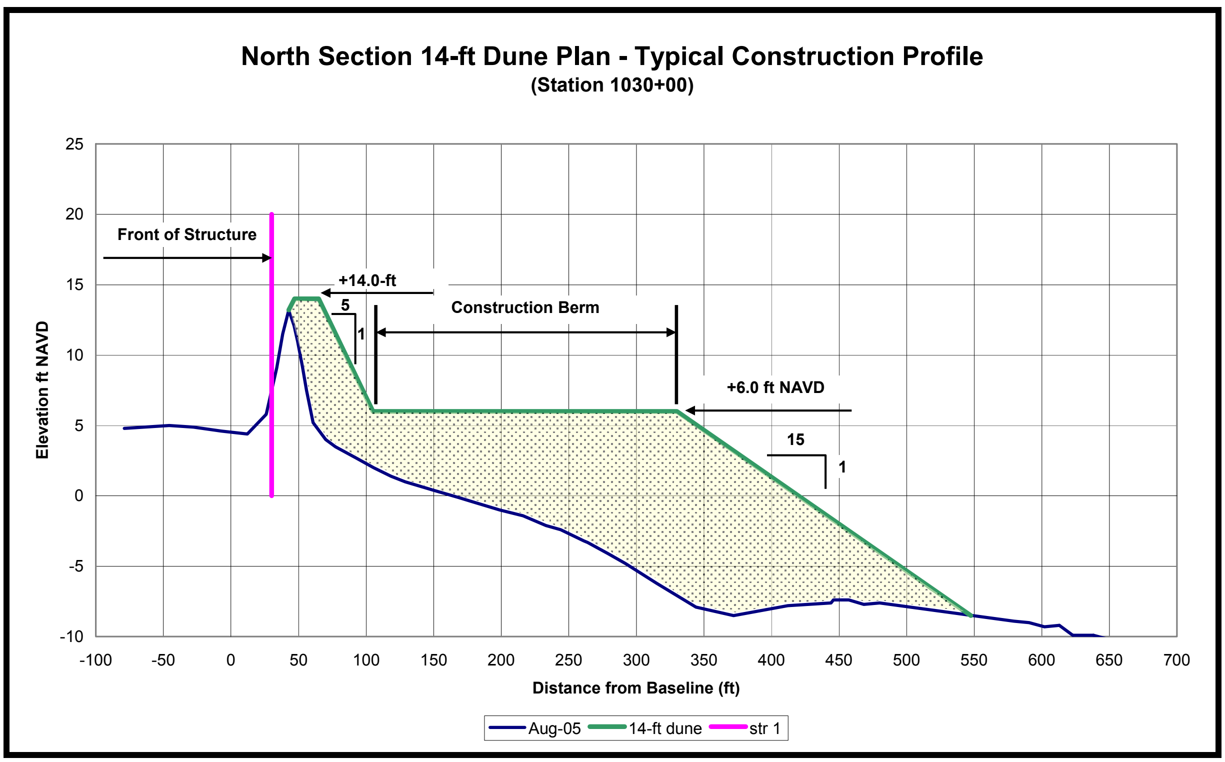


Figure 69. Typical construction profile, North Section 14-foot Dune Plan (Station 1030+00).

19-foot Dune Plan. This plan would include a dune with a crest elevation of +19 feet NAVD with a seaward slope of 1V:5H, fronted by a berm at elevation +6.0 feet NAVD. As with the 14-foot Dune Plan, the dune would tie into the existing dune in areas where existing dune elevations equal or exceed +19 feet NAVD. In areas where the existing dune elevation is less than +19 feet NAVD, the dune would be constructed with a crest width of 25 feet. The 19-foot Dune Plan is the maximum fill section considered for North Topsail Beach and would also include advanced nourishment equal to the other two beach fill plans. Typical construction profiles for the 19-foot Dune Plan are shown in Figures 70 and 71 for the Central and North Sections respectively.

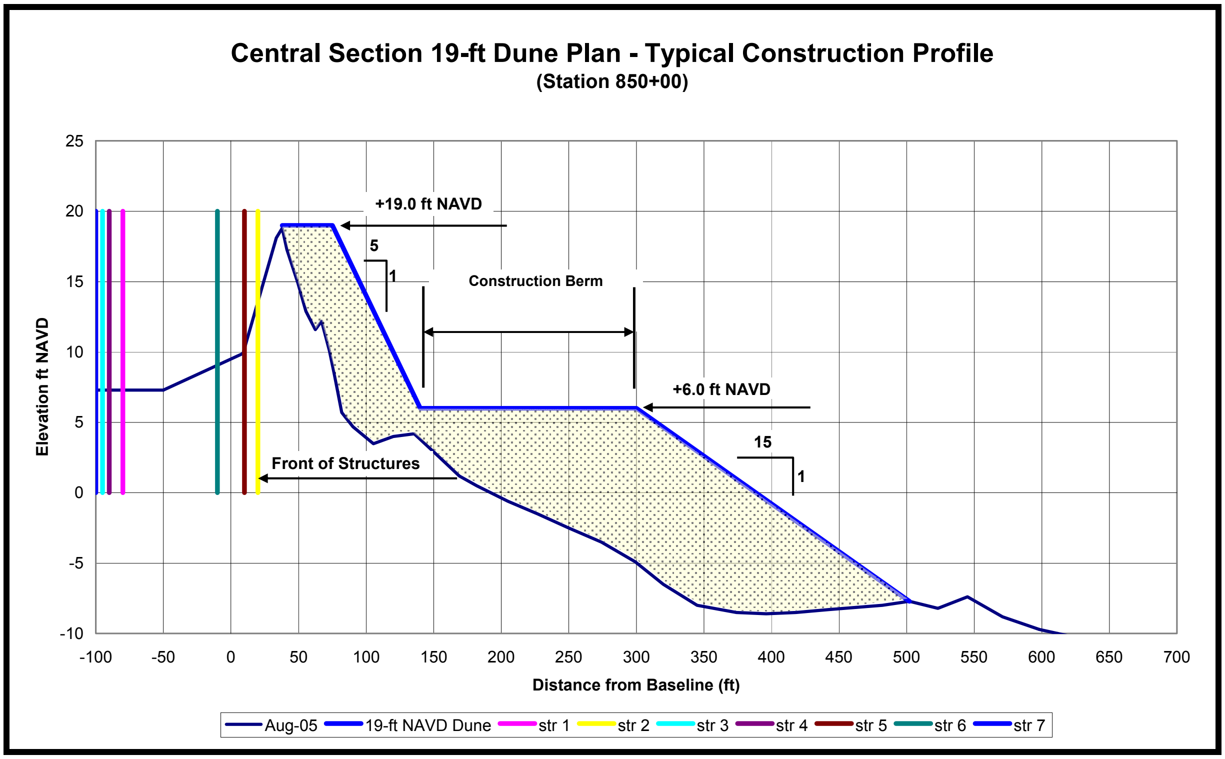


Figure 70. Typical construction profile, Central Section 19-foot Dune Plan (Station 850+00).

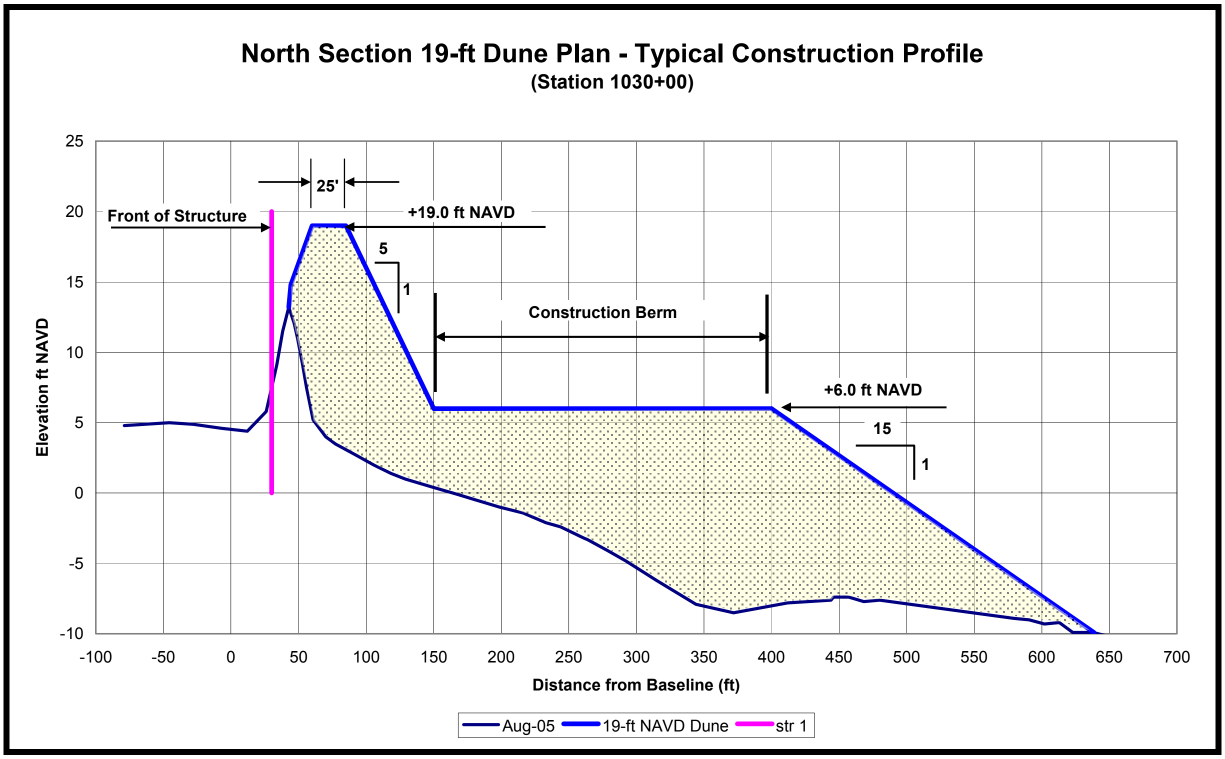


Figure 71. Typical construction profile, North Section 19-foot Dune Plan (Station 1030+00).

Evaluation of the Storm Damage Reduction Potential for the Beach Fill Options

The potential level of storm damage reduction provided by the three beach fill options was evaluated by running the SBEACH simulations for the same suite of 37 storms and the same profiles used to determine storm damages for the No Action Alternative. The damage criteria for the beach fill alternatives were the same as that used for the No Action Alternative except all existing structures were assumed to be in place throughout the 30-year analysis period. The results of the SBEACH analysis for the four profiles and three beach fill designs were used to develop storm impact distances with return intervals of 5, 10, 15, 20, and 25 years applicable to various sections of North Topsail Beach. The storm impact distances used for the three beach fill designs are given in Table 14.

Table 14. Return intervals for storm impact distances – Beach fill options.

Reaches	Baseline Stations	Storm Impact Distances (feet)[1]				
		Return Intervals (years)				
		5	**10**	**15**	**20**	**25**
		Berm Plan				
79 to 85	785+00 to 855+00	105	171	186	201	206
86 to 90	855+00 to 905+00	121	187	225	252	260
91 to 95	905+00 to 955+00	136	203	265	303	313
96 to 103	955+00 to 1035+00	120	194	226	246	261
104 to 116	1035+00 to 1165+00	118	198	215	236	269
		14-foot Dune Plan				
79 to 85	785+00 to 855+00	101	166	178	200	208
86 to 90	855+00 to 905+00	109	174	186	216	242
91 to 95	905+00 to 955+00	117	183	194	233	276
96 to 103	955+00 to 1035+00	102	169	182	218	240
104 to 116	1035+00 to 1165+00	105	174	187	224	245
		19-foot Dune Plan				
79 to 85	785+00 to 855+00	**5**	**10**	**15**	**20**	**25**
86 to 90	855+00 to 905+00	79	129	151	164	172
91 to 95	905+00 to 955+00	88	138	160	172	180
96 to 103	955+00 to 1035+00	97	148	168	181	188
104 to 116	1035+00 to 1165+00	70	131	148	165	174

[1] Storm Impact Distance = Distance from 0-ft NAVD on existing profile to the 0.5-foot erosion point on the post-storm profile.

The area at the extreme north end of North Topsail Beach between Reaches 114 and 116 (baseline stations 1135+00 to 1165+00) is predicted to accrete following the relocation of the ocean bar channel of New River Inlet. Immediately following construction of the beach fill, the added beach width provided by all three beach fill options would not be sufficient to reduce storm damage potentials in these northernmost reaches to acceptable levels. Over the shoreline recovery period, which could take from 5 to 15 years, potential storm damages in these reaches should be reduced until the shorelines attain their maximum predicted recovery. The maximum shoreline recoveries predicted for Reaches 114, 115, and 116 are 110, 180, and 220 feet, respectively.

Potential storm damages in Reaches 114 to 116 for the three beach fill options were based on the full recovery or accretion of the shoreline within each reach occurring over a 15 year period. An example of how storm damage potential would vary over the 30-year analysis period is provided in Figure 72 for the 14-foot Dune Plan. In this example, potential storm damages in Reaches 114 to 116 would decrease from $9.5 million/year immediately after initial construction of the beach fill to $203,500/year by year 15. Storm damage potential would remain at $203,500/year over the remaining 15 years of the analysis period. The equivalent average annual storm damages in Reaches 114 to 116 over the 30-year analysis period would be approximately $2.5 million/year.

By comparison, the sum of the total annual damages in Reaches 114 to 116 for the No Action Alternative was estimated to be about $4.1 million/year (Table 11) or $1.6 million/year greater than with the 14-foot Dune Plan. If the shoreline between baseline stations 1135+00 to 1165+00 (Reaches 114 to 116) occurs more rapidly, the equivalent average annual storm damages in this area would be further reduced.

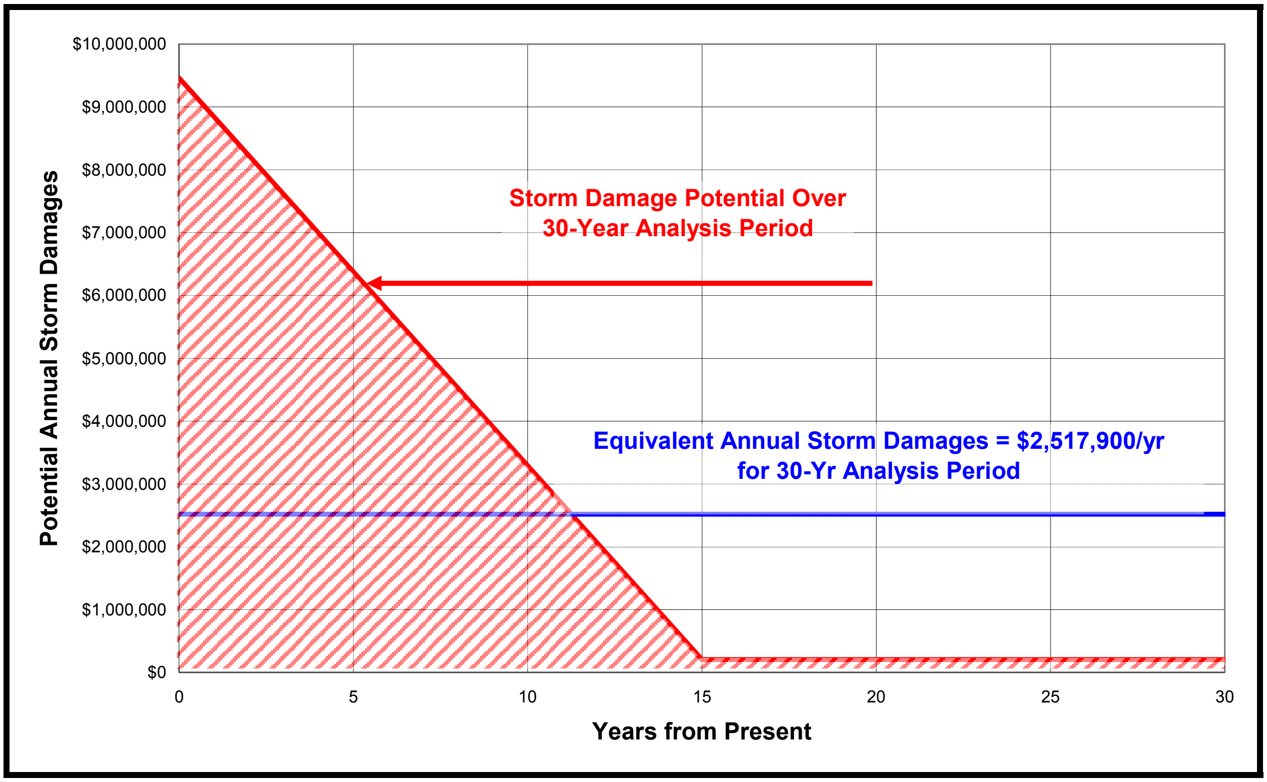


Figure 72. Example of storm damages in Reaches 114 to 116 (baseline stations 1135+00 to 1165+00) for 14-foot Dune Plan over the 30-year analysis period.

Summary of Potential Damage Reduction with the Three Beach Fill Options

The reduction in potential damages in the Central and North Sections of North Topsail Beach that are estimated to occur with the three beach fill options are provided in Table 15. The damage reduction potential is relative to damages that would occur with the No Action Alternative. Damages associated with the No Action Alternative include not only potential storm damages but damages associated with the continuation of long-term erosion. As noted previously, proper maintenance of all three beach fill options over the 30-year analysis period would prevent long-term erosion damages.

Table 15. Reduction in equivalent average annual damages for the three beach fill alternatives relative to the No Action Alternative.

Shoreline Section	No Action Alternative Total Damages	Average Annual Damage Reduction with:		
		Berm Plan	14-foot Dune Plan	19-foot Dune Plan
Central	$5,738,200	$100,100	$3,229,700	$5,415,300
North	$17,688,400	$8,834,900	$11,930,900	$16,027,800
Total	**$23,426,600**	**$8,935,000**	**$15,160,600**	**$21,443,100**

The reduction in average annual damages that would be provided by the Berm Plan would be minimal for the Central Section. Reduction in annual damages for the Berm Plan would be somewhat greater in the North Section with the reduction in annual damages equal to approximately 50% compared to the No Action Alternative. The 14-foot Dune Plan would lower potential damages in the Central Section by almost 56% and over 67% in the North Section. The 19-foot Dune Plan would lower potential damages approximately 94% in the Central Section and 91% in the North Section.

Recommended Beach Fill Option

The 14-foot Dune Plan provides a relatively high level of protection against damages due to long-term erosion and storms compared to the Berm Plan. While the 19-foot Dune Plan would provide the highest level of storm damage protection of the three beach fill options evaluated, construction of the 19-foot Dune Plan would require a much larger volume of material compared to the other two plans.

Geotechnical and beach profile surveys revealed the presence of hardbottom areas located approximately 1,000 feet offshore along portions of the North Topsail Beach shoreline. The placement of the large quantity of material needed to construct the 19-foot Dune Plan could potentially impact these nearshore hardbottom resources. Accordingly, the 14-foot Dune Plan was selected. Details of the design of the 14-foot Dune Plan that were taken to minimize or eliminate potential impacts of the beach fill on the nearshore hardbottom areas is discussed below.

BEACH FILL DESIGN – CENTRAL AND NORTH SECTIONS

Introduction

One of the primary environmental concerns identified during the plan formulation process was the potential for beach nourishment material to migrate seaward following placement and potentially cover two nearshore hardbottom resources located offshore of North Topsail Beach. One nearshore hardbottom area is located between baseline stations 850+00 and 895+00, or offshore of the Hampton Colony development. The other area is located between baseline stations 1030+00 and 1085+00, which begins just north of the Baptist Church and extends past Galleon Bay to approximately the Ship Watch Villas Town Homes. A preliminary design of the beach fill, that involved borrow material with the same mean and standard deviation as the native material, resulted in a potential impact (possible burial) of 13.66 acres of nearshore hardbottom seaward of the Hampton Colony and 2.91 acres seaward of the northern area situated between baseline stations 1030+00 and 1085+00.

In order to minimize or eliminate this potential negative environmental impact, an innovative beach nourishment design was developed using the selective placement of coarse grain borrow material in the nearshore hardbottom areas. Coarse material is available from portions of the offshore borrow area and from construction of the new ocean bar channel in New River Inlet.

Point of Intercept Concept

The selective use of coarse grain material in the nearshore hardbottom areas was based on a relationship between the mean grain size of beach material and the equilibrium shape of a beach profile developed by Dr. Robert Dean and reported in the Corps of Engineers Coastal Engineering Manual (USACE, 2002). Dean's equilibrium profile is defined as:

$$Y = AX^{2/3}$$

where:

Y = Depth below the shoreline
A = Dean's A-factor
X = Distance seaward of the shoreline

Dean's A-factor is usually associated with the grain size of the beach material with coarse material having larger A-factors and corresponding steeper slopes. Table III-3-3 in the Corps of Engineers Coastal Engineering Manual provides the relationship between mean grain size and Dean's A-factor for normal beach profiles (USACE, 2002). However, where offshore hardbottom is present, the A-factor can be larger, primarily due to the effect of the hardbottom on wave breaking (Muñoz-Perez, et al, 1999). This effect is known as a "perched beach".

Large sections of North Topsail Beach have hardbottoms located close to shore which produce the "perched beach" effect. Accordingly, the A-factor for each profile station along North Topsail Beach was estimated from the August 2005 beach profile survey conducted by CPE using the observed offshore distances and elevations. The mean grain sizes at each profile line, reported in Table 3, were used to estimate the "theoretical" A-factor from Table III-3-3 in the Coastal Engineering Manual (USACE, 2002). The comparison of the "theoretical" A-factor, which is based on mean grain size of the native beach, and the "perched beach" A-factor, which is based on the actual shape of the existing beach profiles, is presented in Figure 73.

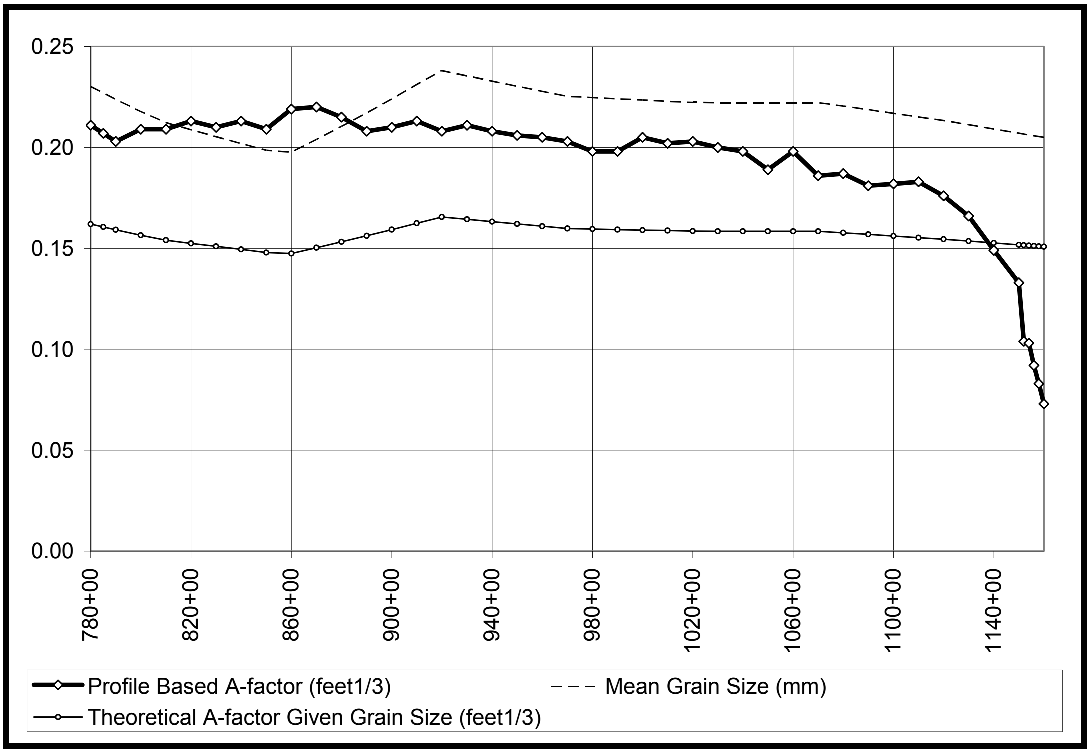


Figure 73. A-factors and grain sizes, North Topsail Beach, NC.

As shown in Figure 73, the "theoretical" or gain size A-factor and profile-based, or "perched beach" A-factor varies with location. To simplify the analysis, an average ratio between the "theoretical" and "perched beach" A-factor (A_{rp}/A) was defined for the each of the following areas:

Table 16. Perched beach A-factor ratio, North Topsail Beach, NC.

Profile Lines	**A_{rp} / A**
Central Section:	
780+00 to 830+00	1.34
840+00 to 900+00	1.41
910+00 to 950+00	1.28
North Section:	
960+00 to 1010+00	1.26
1020+00 to 1090+00	1.22

Beach Fill Sources

The paleo channel area located within the offshore borrow area contains 357,000 cubic yards of material with an average grain size of 0.33 mm. Coarse material, with a mean grain size of 0.33 mm, would also be available from New River Inlet from the construction of the -18 ft NAVD x 500-foot wide channel. The maximum volume of material that would be available from New River Inlet totals 635,800 cubic yards based on the August 2005 hydrographic survey of New River Inlet.

Beach Fill Widths

The design widths of the beach fill in various sections of North Topsail Beach are based on maintenance of a design shoreline position over a 4 year project life. Historic erosion rates for North Topsail Beach, given in Figure 10 were used to determine the added width of beach needed to account for 4 years of erosion between periodic nourishment operations. In this regard, the maximum shoreline recession for either the 1963 to 1983 or the 1983 to 2002 time period was used to determine the added beach width needed to account for 4-years of erosion. The design width of the beach for the 14-foot Dune Plan and the advance beach width are given in Table 17. The sources of the beach fill material that would be used to construct the 14-foot Dune Plan in the various reaches is also given in Table 17. A discussion of the impacts of these beach fill sources follows.

Table 17. Design beach fill dimensions, 14-foot Dune Plan, North Topsail Beach, NC.

Profile Lines	Beach Width in feet (from August 2005 +6' NAVD)			Fill Type
	Design	Advance	TOTAL	
Central Reach:				
780+00 to 830+00	50	12	62	Fine/Coarse Mix
840+00 to 900+00	48	17	65	Coarse
910+00 to 950+00	50	21	71	Fine/Coarse Mix
North Reach:				
960+00 to 1010+00	75	21	96	Fine/Coarse Mix
1020+00 to 1140+00	57	35.1	92.1	Inlet
1150+00	57	40.2	97.4	Inlet
1160+00	57	51	108	Inlet

Beach Fill Profiles

The source of the beach fill material designated in Table 17 was selected to minimize impacts on the nearshore hardbottoms. Also, the areas that would be constructed with the coarser material have been extended 1,000 feet south of the southern limits of the nearshore hardbottom areas and 500 feet north of the nearshore hardbottom areas to allow for possible alongshore movement of the material. Materials from New River Inlet would be placed near the inlet from profile lines

1040+00 to 1160+00. Coarse material from the offshore borrow area, designated as the Coarse Sand, would be deposited between baseline stations 840+00 to 900+00 and 1020+00 to 1030+00. Along the remainder of the fill area, a mix of Channel Sand and material from other sections of the offshore borrow area would be used in order to optimize beach fill performance. The composite grain size of these mixed sands would be approximately 0.21 mm.

Translated Profile

Post nourishment profile shapes and fill volumes can be estimated assuming a translated beach profile. The translated profile assumes that the equilibrium beach profile will be similar in shape to the existing beach profile. To account for unequal native and beach fill A-factors, the following shape correction is applied below the waterline (Coastal Engineering Manual, pp. V-4-35, USACE, 2000):

$$W_{add} = Y^{3/2}[A_F^{-3/2} - A_N^{-3/2}]$$

where

Y = Depth below the shoreline.
A_F = Dean's (perched beach) A-factor for the fill material.
A_N = Dean's A-factor based on the existing beach profile.

This approach is summarized in Figure 74.

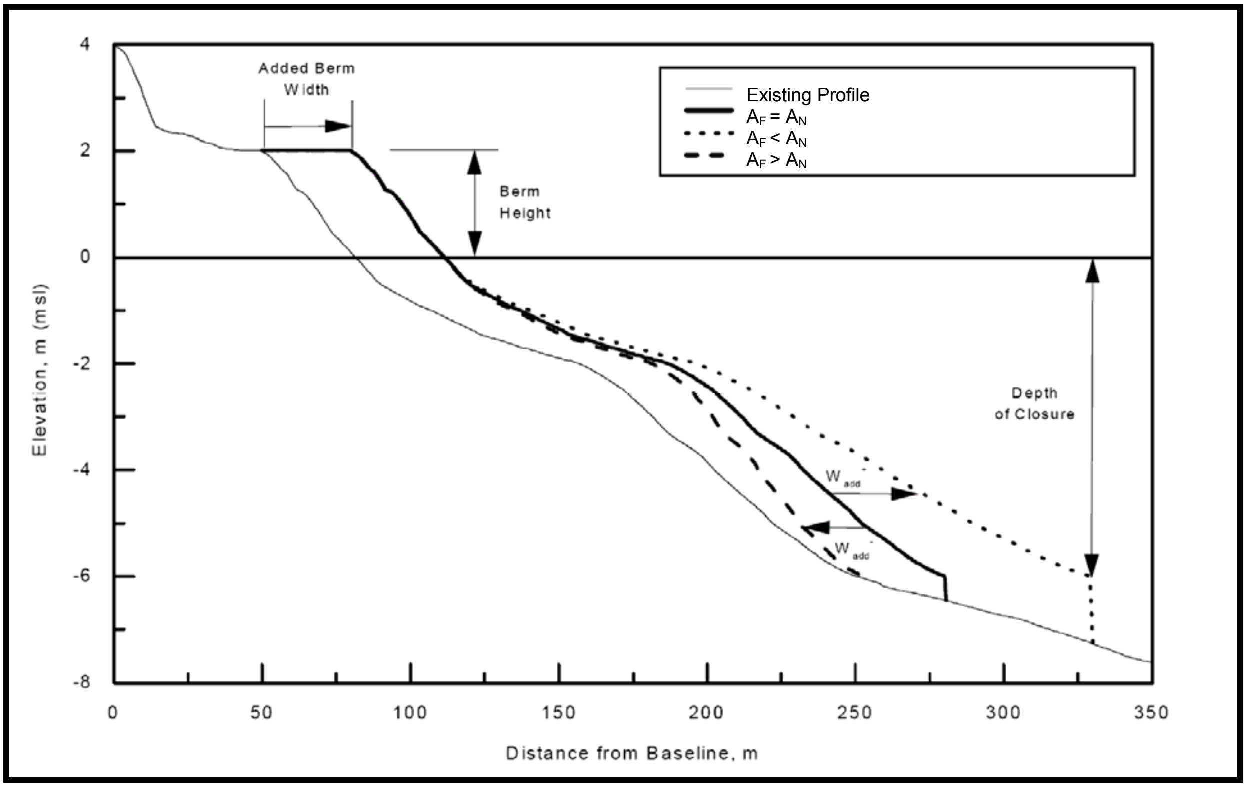


Figure 74. Translated equilibrium profiles (Coastal Engineering Manual, USACE, 2002).

Beach Fill Volumes

The corresponding fill volumes may be calculated according to the following procedure (Coastal Engineering Manual, pp. V-4-43 to V-4-45, USACE, 2002):

$$I = W(A_N/D_C)^{3/2} + (A_N/A_F)^{3/2}$$

$$V = WB + 0.6(D_C/A_F)^{5/2}\{A_N[1 + W(A_F/D_C)^{3/2}]^{5/3} - A_F\} \quad \text{for } I > 1$$

$$V = WB + 0.6W^{5/3}A_NA_F/(A_F^{3/2} - A_N^{3/2})^{2/3} \quad \text{for } I \leq 1$$

where:

- V = Berm volume per lineal foot.
- W = Design berm width from existing berm.
- B = Design berm elevation above the shoreline.
- D_C = Depth of closure below the shoreline.
- A_F = Dean's (perched beach) A-factor for the fill material.
- A_N = Dean's A-factor based on the existing beach profile.

The design berm elevation is +6 feet NAVD, the shoreline elevation is +1.4 feet NAVD, and the depth of closure lies near -20 feet NAVD in most locations. The values of B and D_C relative to the shoreline elevation are therefore 4.9 and 22.1 feet, respectively. Beach fill volumes for the berm and dune associated with the 14-foot Dune Plan are plotted in Figure 75 and given in Table 18.

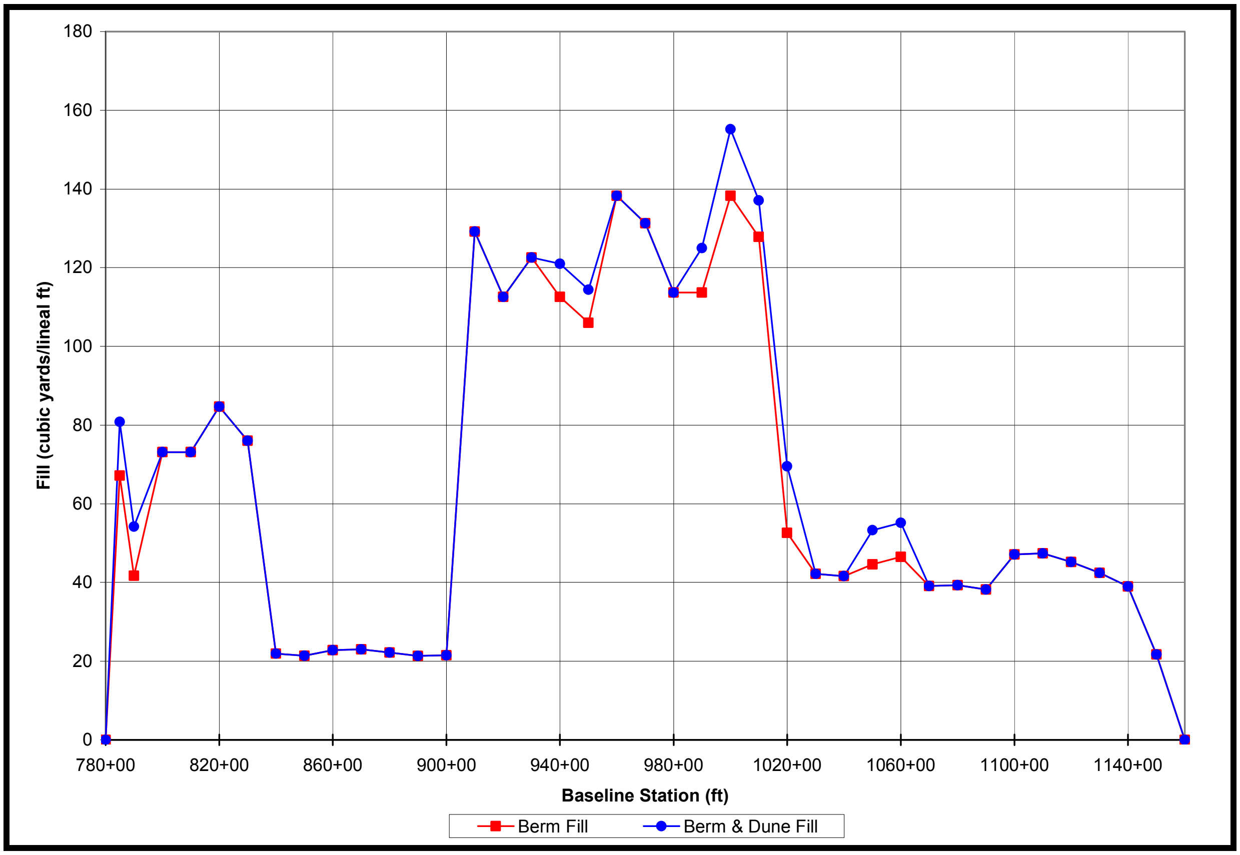


Figure 75. Fill volumes, 14-foot Dune Plan, North Topsail Beach, NC.

Table 18. Beach fill volumes, 14-foot Dune Plan, North Topsail Beach, NC.

Profile Line	Fill Length	Beach Fill Volume (CY)				Source of Beach Fill [1]
	(ft)	Berm	Dune	Inlet Induced Erosion Advanced Nourishment	Total	
780+00	250	0	0	0	0	Offshore Mix
785+00	500	33,600	6,800	0	40,400	Offshore Mix
790+00	750	41,700	12,500	0	54,200	Offshore Mix
800+00	1,000	73,100	0	0	73,100	Offshore Mix
810+00	1,000	73,100	0	0	73,100	Offshore Mix
820+00	1,000	84,700	0	0	84,700	Offshore Mix
830+00	1,000	76,000	0	0	76,000	Offshore Mix
840+00	1,000	21,900	0	0	21,900	Offshore Coarse
850+00	1,000	21,400	0	0	21,400	Offshore Coarse
860+00	1,000	22,800	0	0	22,800	Offshore Coarse
870+00	1,000	23,000	0	0	23,000	Offshore Coarse
880+00	1,000	22,200	0	0	22,200	Offshore Coarse
890+00	1,000	21,300	0	0	21,300	Offshore Coarse
900+00	1,000	21,500	0	0	21,500	Offshore Coarse
910+00	1,000	129,200	0	0	129,200	Offshore Mix
920+00	1,000	112,600	0	0	112,600	Offshore Mix
930+00	1,000	122,600	0	0	122,600	Offshore Mix
940+00	1,000	112,600	8,400	0	121,000	Offshore Mix
950+00	1,000	106,000	8,400	0	114,400	Offshore Mix
960+00	1,000	138,300	0	0	138,300	Offshore Mix
970+00	1,000	131,300	0	0	131,300	Offshore Mix
980+00	1,000	113,700	0	0	113,700	Offshore Mix
990+00	1,000	113,700	11,300	0	125,000	Offshore Mix
1000+00	1,000	138,300	16,900	0	155,200	Offshore Mix
1010+00	1,000	127,800	9,300	0	137,100	Offshore Mix
1020+00	1,000	52,600	16,900	0	69,500	Offshore Coarse
1030+00	1,000	42,200	0	0	42,200	Offshore Coarse
1040+00	1,000	41,600	0	0	41,600	New River Inlet
1050+00	1,000	44,600	8,700	0	53,300	New River Inlet
1060+00	1,000	46,500	8,700	0	55,200	New River Inlet
1070+00	1,000	39,100	0	0	39,100	New River Inlet
1080+00	1,000	39,300	0	12,120	51,420	New River Inlet
1090+00	1,000	38,200	0	12,120	50,320	New River Inlet
1100+00	1,000	47,100	0	12,120	59,220	New River Inlet
1110+00	1,000	47,400	0	12,120	59,520	New River Inlet
1120+00	1,000	45,200	0	12,120	57,320	New River Inlet
1130+00	1,000	42,400	0	12,120	54,520	New River Inlet
1140+00	1,000	39,000	0	12,120	51,120	New River Inlet
1150+00	1,000	21,700	0	12,120	33,820	New River Inlet
1160+00	1,000	14,600	0	12,120	26,720	New River Inlet

[1]Shaded areas would be nourished with coarse material from the offshore borrow area or New River Inlet

Construction of the beach fill between baseline stations 1070+00 and 1160+00 would be accomplished using the coarse material from New River Inlet. Due to the coarseness of the inlet material, construction of the 14-foot Dune Plan would only require 483,080 cy while construction of the new channel could result in the removal of 544,400 cubic yards of coarse material from the inlet. Note an additional 91,400 cubic yards of mostly clay would also be removed and deposited in an upland disposal site. The estimated volume of material that would be removed to construct the new channel was based on the August 2005 CPE survey of the inlet. At the time of construction, the actual volume to be removed could vary up or down. The volume of material removed from New River Inlet over that needed to construct the beach fill project would be evenly distributed between baseline stations 1120+00 and 1160+00. Based on the present channel volume estimated, an excess of 61,320 cubic yards over that required for the beach fill project would be removed from the inlet to construct the channel. The even distribution of this volume of material between 1120+00 and 1160+00 would place an additional 15.3 cubic yards/lineal foot along this 4,000 foot section of North Topsail Beach above that needed for the 14-foot Dune Plan.

The additional 109,100 cy of material to be placed to counter act the inlet induced erosion between stations 1080+00 and 1160+00 was determined by reviewing the yearly volumetric losses between stations 1080+00 and 1170+00.

The dune volume for each profile station given in Table 18 is based on existing conditions. In this regard, the Town of North Topsail recently completed a post-Hurricane Ophelia dune restoration program that included scraping material off the beach foreshore to the dune and truck haul of over 45,000 cubic yards of sand from an upland borrow area. The volume actually needed to construct the 14-foot NAVD dune feature will be adjusted based on profile surveys taken immediately prior to construction and field directions provided by the construction supervisor. The intent of the beach fill design is to provide a 14-foot NAVD dune along the entire length of the beach in the Central and North Sections.

Figures 76A to 76C show the general layout of the beach fill plan for the Central and North Sections. Nearshore hardbottom areas are indicated by the solid line offshore while the equilibrium toe of the fill is shown as a dashed line.

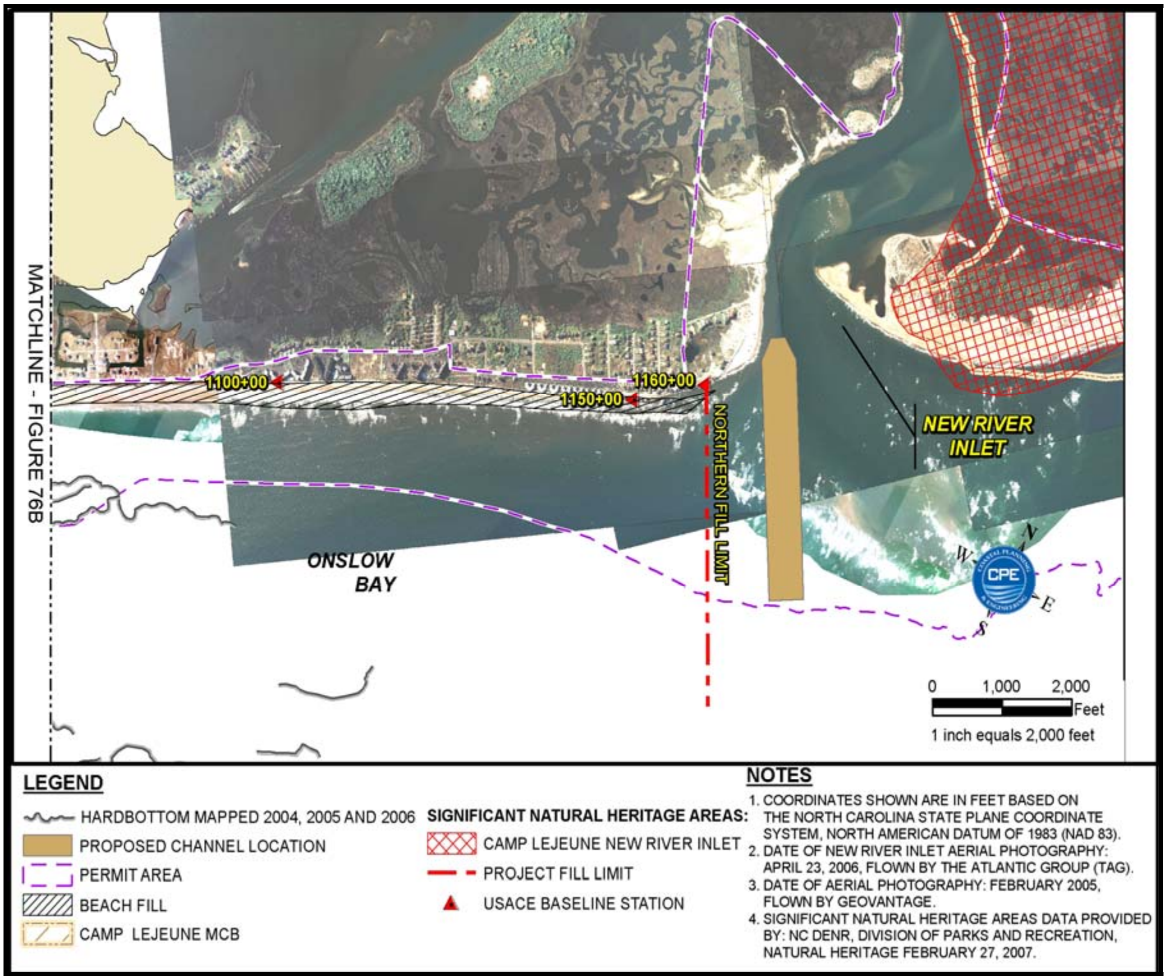


Figure 76A. Beach fill plan – Central and North Sections.

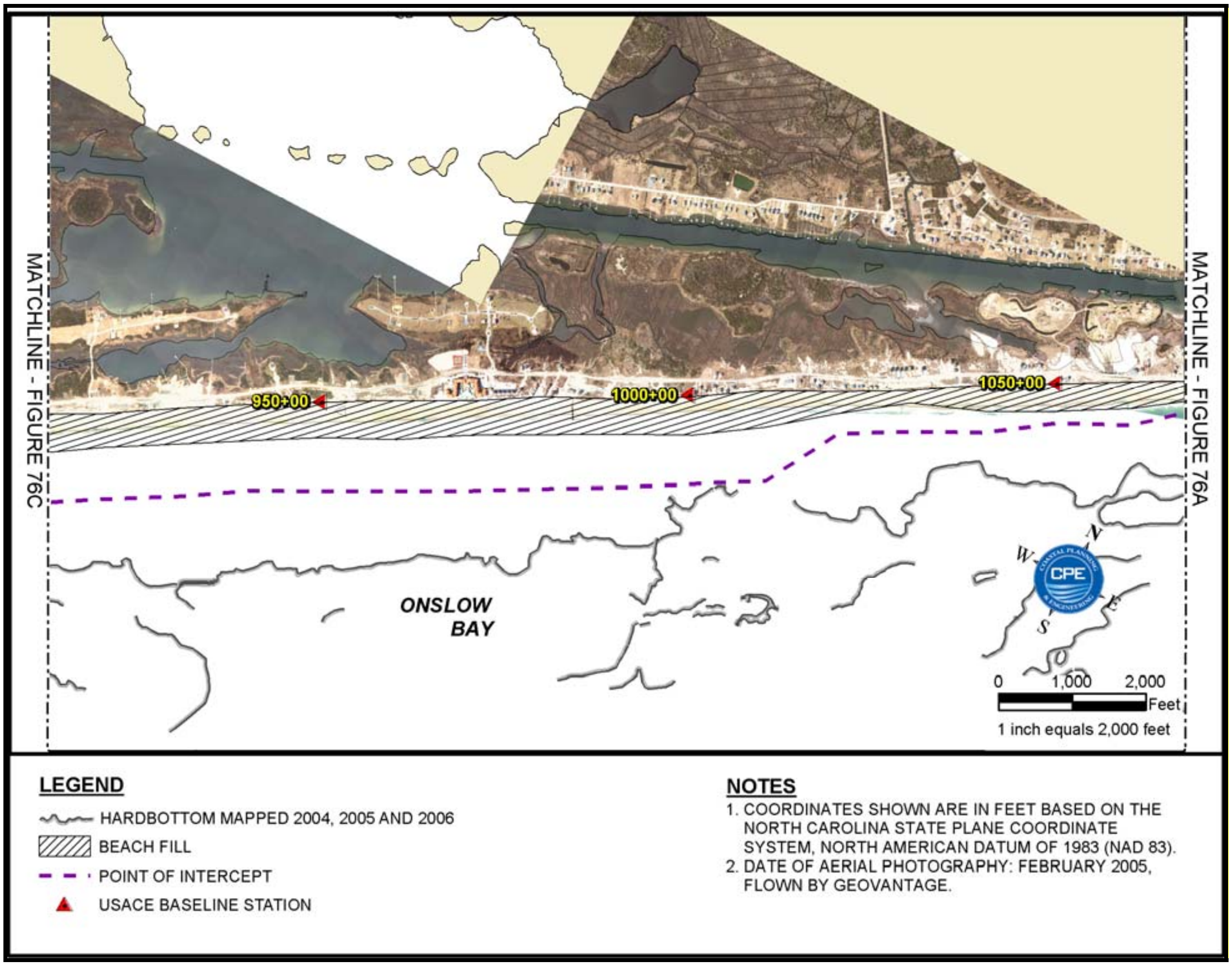


Figure 76B. Beach fill plan – Central and North Sections.

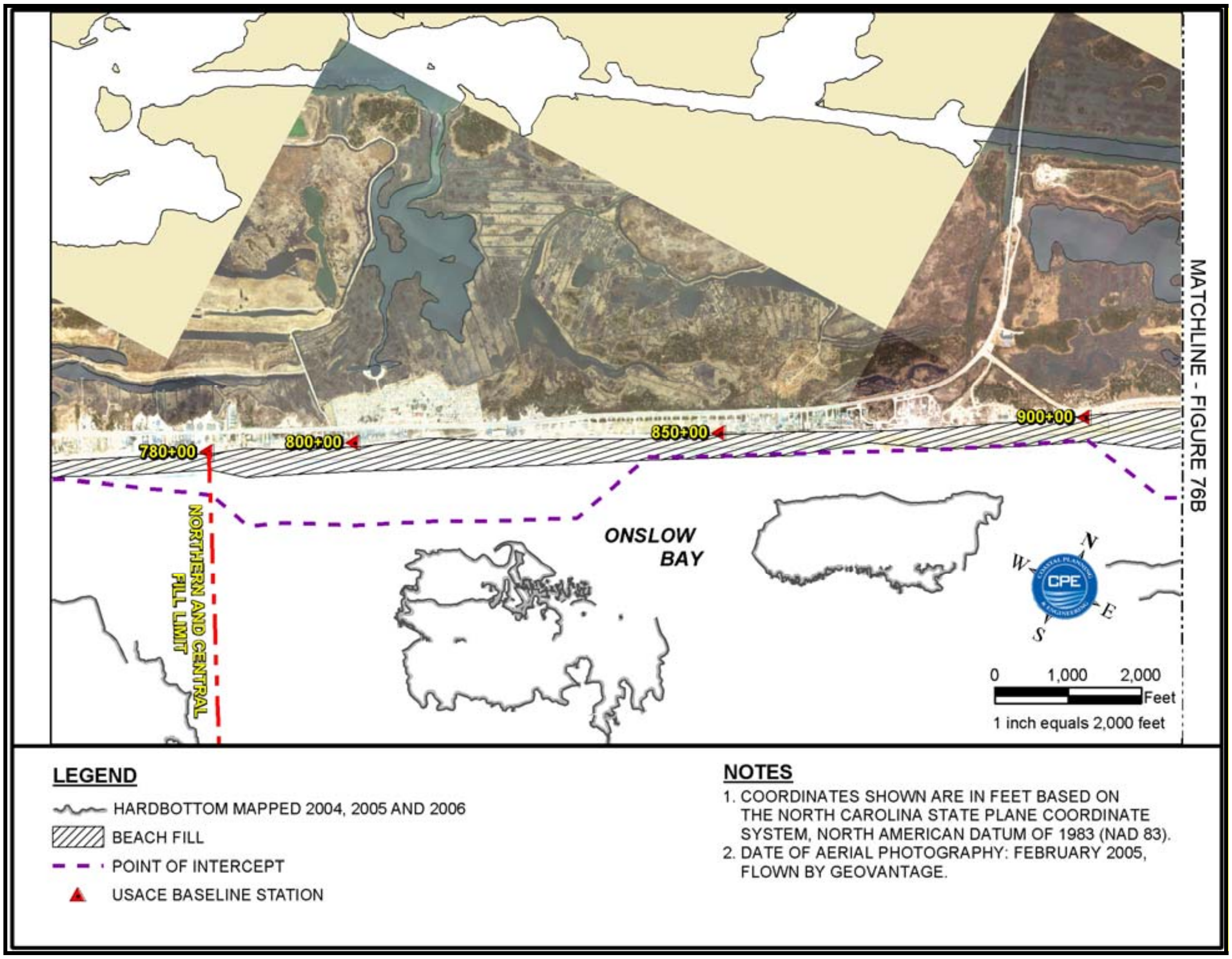


Figure 76C. Beach fill plan – Central and North Sections.

Point of Intercept Versus Location of Nearshore Hardbottom

The location of the point of intercept of the beach fill with the existing profile, relative to the baseline, is given in Table 19 along with the location of the landward edge of the nearshore hardbottom for each 1,000-foot baseline station within the Central and North Sections. In areas where the coarse grain borrow material would be used, the equilibrium toe of the fill is located less than 400 feet from the baseline while the nearshore hardbottom is located 1,000 feet or more from the baseline.

Table 19. Equilibrium toe of the beach fill versus landward edge of the nearshore hardbottom.

Profile Station	Distance to Hardbottom from Baseline	Distance to Point of Intercept from Baseline	Source/Type of Beach Fill Material
785+00	NA[(1)]	1130	Offshore Mix
790+00	NA	1170	Offshore Mix
800+00	1210	1200	Offshore Mix
810+00	1490	1220	Offshore Mix
820+00	1380	1140	Offshore Mix
830+00	2760	1190	Offshore Mix
840+00	NA	350	Offshore Coarse
850+00	NA	350	Offshore Coarse
860+00	950	360	Offshore Coarse
870+00	900	350	Offshore Coarse
880+00	950	360	Offshore Coarse
890+00	NA	330	Offshore Coarse
900+00	2010	340	Offshore Coarse
910+00	2210	1260	Offshore Mix
920+00	2500	1280	Offshore Mix
930+00	2390	1250	Offshore Mix
940+00	2280	1250	Offshore Mix
950+00	2370	1290	Offshore Mix
960+00	2120	1310	Offshore Mix
970+00	2330	1290	Offshore Mix
980+00	1960	1310	Offshore Mix
990+00	2010	1280	Offshore Mix
1000+00	1320	1280	Offshore Mix
1010+00	1440	1310	Offshore Mix
1020+00	1600	350	Offshore Coarse
1030+00	1170	340	Offshore Coarse
1040+00	1270	360	New River Inlet
1050+00	1700	390	New River Inlet
1060+00	1220	380	New River Inlet
1070+00	1220	370	New River Inlet
1080+00	1590	372	New River Inlet
1090+00	1860	382	New River Inlet
1100+00	3230	382	New River Inlet
1110+00	2100	412	New River Inlet
1120+00	NA	412	New River Inlet
1130+00	NA	362	New River Inlet
1140+00	NA	322	New River Inlet
1150+00	3630	197	New River Inlet

[(1)]NA = Nearshore Hardbottom not apparent from Sidescan or Profile Surveys

Summary Beach Fill Design – Central and North Sections

The selective placement of coarse grain material from the offshore borrow area and New River Inlet would result in the equilibrium toe of the fills in the nearshore hardbottom areas being located well landward of the edge of the nearshore hardbottoms. For the area between baseline stations 840+00 and 900+00, the equilibrium toe of the fill would merge with the existing profile 450 feet to 600 feet landward of the hardbottom area. Between baseline stations 1020+00 and

1090+00, the toe of the fill would be 800 feet to 1200 feet landward of the hardbottoms. The equilibrium toe of the fill associated with the use of the coarse grain borrow material combined with the placement of the coarse grain material 1000 feet north and 500 feet south of the of the hardbottom areas should eliminate impacts of the beach fill on these nearshore resources.

The volume of material required to construct the 14-foot Dune Plan using the coarse material in the nearshore hardbottom areas and a mix of offshore borrow material in the other areas totals 2,700,880 cubic yards, which includes the 633,180 cubic yards of additional material from construction of the new channel in New River Inlet. Previous estimates of the fill volume that were based on borrow material characteristics equal to the native material resulted in a total fill volume of 3,344,300 cubic yards. Therefore, the selective use of the coarse gain material not only results in the equilibrium toe of the fill being located well landward of the edge of the nearshore hardbottoms, but the volume of material needed to construct the project is reduced by 643,420 cubic yards compared to the use of other available but finer material. Since the coarser material will be retained on the upper portions of the profile, the added beach width, and thus the level of protection associated with the coarse grain material would be the same.

Periodic Nourishment Requirement

Nourishment volumes needed to maintain the advanced nourishment beach widths given in Table 17 would be equal to 56,000 cubic yards/year for the Central Section and 72,000 cubic yards/year for the North Section. Prior to the predicted recovery along the extreme north end of North Topsail Beach associated with the new channel in New River Inlet, erosion rates on the extreme north end of the fill are likely to be higher. Accordingly, the estimated nourishment requirement for the North Section was increased by 25% to a total of 90,000 cubic yards/year. For the 4-year nourishment cycle, the nourishment requirement for the Central and North Sections would be 224,000 and 360,000 cubic yards, respectively or a total of 584,000 cubic yards every 4 years.

Most if not all of the periodic nourishment material would be derived from maintenance of the proposed new bar channel in New River Inlet and normal maintenance of the navigation channel in Cedar Bush Cut. Shoaling of the new channel is estimated to capture 627,000 cubic yards every 4 years. Maintenance dredging in Cedar Bush Cut, which is performed by the Corps of Engineers, has historically averaged 48,000 cubic yards/year which would yield 192,000 cubic yards every 4 years. Thus, over a 4-year period, shoaling of the new channel in New River Inlet and Cedar Bush Cut would total 819,000 cubic yards or an average of approximately 205,000 cubic yards/year.

The new channel position and alignment would have to be maintained in order to produce and maintain the predicted shoreline recoveries on the extreme north end of North Topsail Beach. Therefore, regardless of the beach nourishment needs, all of the material that collects in the new channel would have to be removed and distributed along the Central and North Sections of the North Topsail Beach shoreline. Continued maintenance of Cedar Bush Cut by the Corps of Engineers will depend on future federal funding, which has become problematic during recent years.

If the Corps is forced to suspend maintenance of Cedar Bush Cut, supplemental periodic nourishment material may have to be obtained from the offshore borrow area. In this event, the finer grained offshore borrow material would only be used in areas where hardbottom resources are located sufficiently offshore not to be impacted by post-nourishment fill adjustments. The coarser shoal material from New River Inlet would be primarily allocated to nourish the areas where hardbottom resources are located relatively close to shore.

BEACH FILL DESIGN - SOUTH SECTION

Plan Formulation – Interim Beach Fill

The formulation of the federal storm damage reduction project for the southern 3.85 miles (20,320 feet) of North Topsail Beach (South Section) by the Corps of Engineers was based on the condition of the 2002 shoreline. Following consultation with the Corps of Engineers, the volume of material placed within the South Section to provide interim protection until such time that the Federal storm damage reduction project is implemented, should be based on: (1) restoring the 2002 shoreline condition and (2) providing advanced nourishment sufficient to maintain the 2002 shoreline condition until the federal storm damage reduction project is implemented.

The projected construction date for the federal project is somewhat uncertain due to federal budget priorities that have slowed funding for the feasibility study. Presently, the Corps is predicting that the project along the South Section would be constructed in 2012; however, this could be pushed back to 2014. Construction of the non-Federal project for North Topsail Beach is scheduled to occur in two phases with the first phase taking place between December 2007 and 31 March 2008 followed by the second phase between 16 November 2008 and 31 Mar 2009. Construction of the interim project for the South Section would occur during the second construction phase. Therefore, the interim beach fill must contain enough material to account for losses that could occur between the October 2006 survey and completion of construction of the federal project, an interim period of at least 8 years.

Restoration of 2002 Shoreline Condition

CPE conducted a beach profile survey of the South Section during October 2006. The survey included 21 profiles spaced at 1,000-foot intervals from baseline stations 580+00 to 780+00. Note that the southern Town limit of North Topsail Beach is located at approximately baseline station 581+80. The 2006 profile survey was compared to a Corps of Engineer’s beach profile survey conducted in March 2002. Examples of the comparison of the two profile surveys are shown in Figures 77 to 80 (profile stations 600+00, 640+00, 680+00, and 760+00).

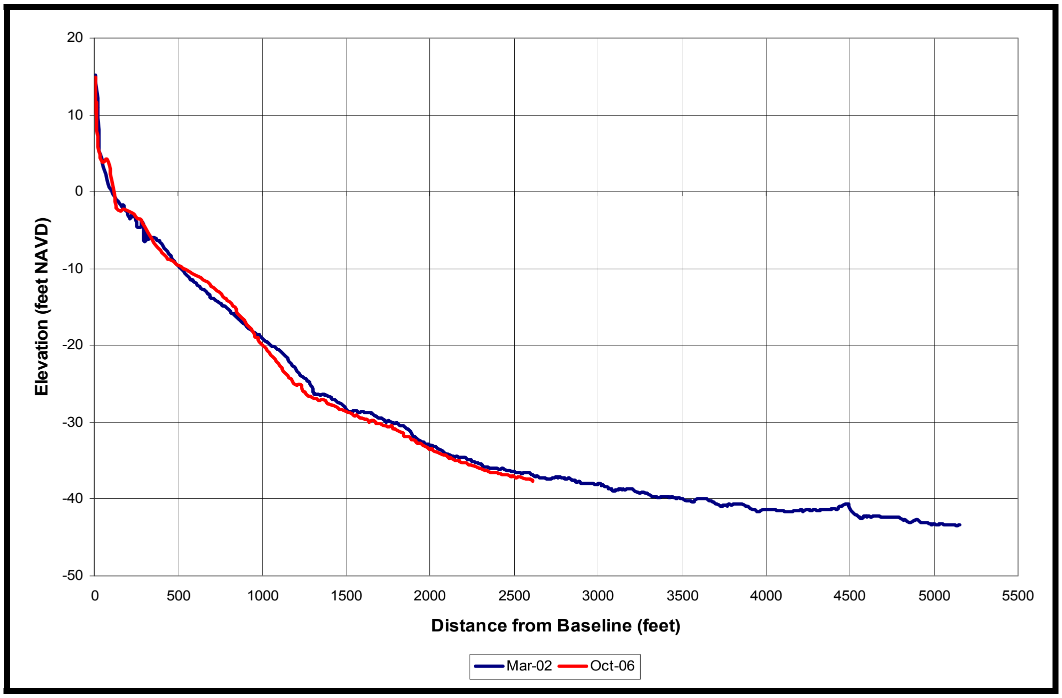


Figure 77. March 2002 profile survey by Corps of Engineers with October 2006 profile survey by CPE for station 600+00.

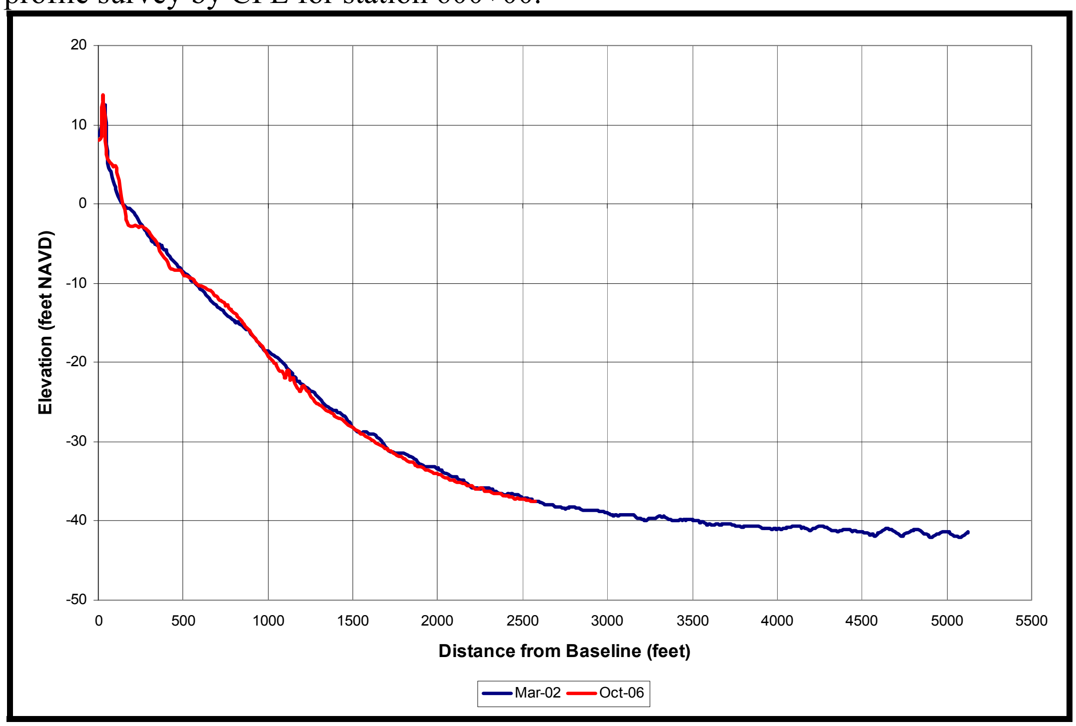


Figure 78. March 2002 profile survey by Corps of Engineers with October 2006 profile survey by CPE for station 640+00.

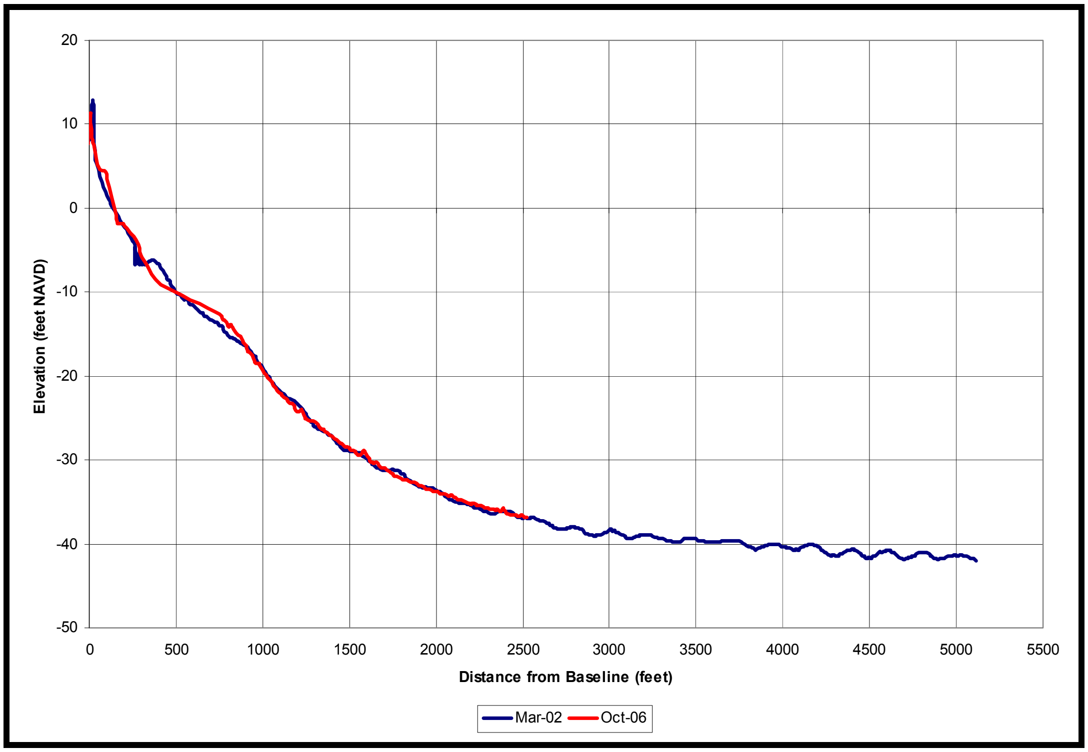


Figure 79. March 2002 profile survey by Corps of Engineers with October 2006 profile survey by CPE for station 680+00.

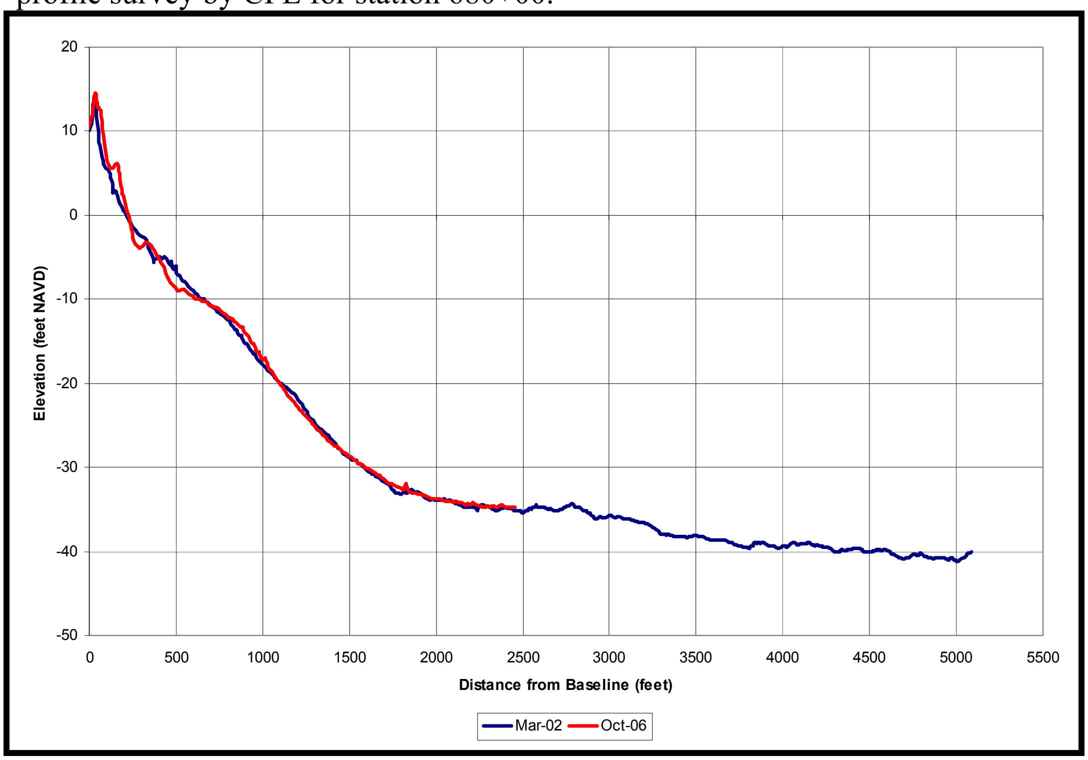


Figure 80. March 2002 profile survey by Corps of Engineers with October 2006 profile survey by CPE for station 760+00.

Beach Profile Volume Change – March 2002 to October 2006

The results of the profile comparison between March 2002 and October 2006 found that the southern section of the Town's shoreline gained approximately 154,000 cubic yards between the baseline and the -20-foot depth contour (depth limit of active profile) while the mean high water shoreline moved an average of 18 feet seaward. Table 20 provides a summary of the volume change between profile stations and the movement of the mean high water shoreline at each profile station. Volume change computations extend from the southern Town limit (station 581+80) to the approximate boundary of the CBRS (785+00) and were rounded to the nearest 1,000 cubic yards.

The behavior of the South Section during this 4.6 year period deviates from historic trends observed during the periods 1963-1983 and 1983-2002 shown in Figure 10. During both of these periods, the South Section eroded, averaging -2.4 feet/year and -1.2 feet/year for the two periods, respectively. Apparently, the beach in the South Section is still undergoing recovery from the severe storms that impacted the area between 1996 and 1999 or is gaining material at the expense of the beaches to the north. With regard to storm impacts, the March 2002 survey conducted by the Corps probably captured some of the residual erosion caused by the storms while the October 2006 survey represented additional post-storm recovery. Also, the shorelines to the north experienced rather high rates of erosion between 1983 and 2002 compared to the South Section. Given the predominant movement of littoral material to the south, the material eroded from the beaches to the north would have been transported into the South Section.

Based on this comparison, no beach fill is needed to restore the beach to the March 2002 condition, however, anticipated erosion between now and the time the federal storm damage reduction project is implemented as well as the possible impact of storms on the shoreline during this interim period, needs to be addressed.

Table 20. South Section volume change between March 2002 and October 2006.

From Station:	To Station:	Volume Change between Stations (CY)	Change in Mean High Water Shoreline Position	
			Station	Change (ft)
581+80	590+00	5,000	580+00	1
590+00	600+00	11,000	590+00	10
600+00	610+00	1,000	600+00	27
610+00	620+00	-5,000	610+00	-8
620+00	630+00	-3,000	620+00	-13
630+00	640+00	-3,000	630+00	-13
640+00	650+00	1,000	640+00	23
650+00	660+00	7,000	650+00	-12
660+00	670+00	17,000	660+00	21
670+00	680+00	15,000	670+00	25
680+00	690+00	3,000	680+00	23
690+00	700+00	3,000	690+00	28
700+00	710+00	4,000	700+00	-3
710+00	720+00	1,000	710+00	25
720+00	730+00	8,000	720+00	28
730+00	740+00	16,000	730+00	26
740+00	750+00	24,000	740+00	40
750+00	760+00	20,000	750+00	45
760+00	770+00	11,000	760+00	29
770+00	780+00	12,000	770+00	41
780+00	785+00	6,000	780+00	41
Total 581+80 to 785+00		**154,000**	**Average**	**18**

South Section Advanced Nourishment

There are two components associated with providing sufficient advanced nourishment to maintain the beach in the South Section and prevent the loss of infrastructure and development. The first component addresses losses due to long-term erosion while the second deals with possible losses due to the advent of coastal storms during the 8-year interim period.

Long-Term Erosion

Even though the South Section has experienced some accretion during the last 4.6 years (March 2002 to October 2006), historically shoreline trend for the South Section has been erosion. Due to uncertainties associated with future changes, the advanced nourishment needed to counter long-term erosion was based on the larger of the erosion rates observed between 1963-1983 and 1983-2003. The erosion rates for these two periods are shown in Figure 11 and tabulated in Table 21. Also provided in Table 21 is the maximum erosion rate for each profile station observed for the two periods and the added beach width needed at each profile station to counter long-term erosion during the 8-year interim period. The average additional beach width needed for the South Section is 24 feet. The volume of in place material that would be needed to widen the 20,320 lineal feet of beach in the South Section by an average of 24 feet and provide a 1,000-foot transition section on the south end of the project would be 500,000 cubic yards.

Table 21. Shoreline change rates used to determine advanced maintenance for the South Section

Profile Station	1963 to 1983 Shoreline Change Rate (ft/yr)	1983 to 2002 Shoreline Change Rate (ft/yr)	Maximum Shoreline Change Rate (ft/yr)	Added Beach Width Needed for 8-yr Interim Period
580+00	-2.5	-1.9	-2.5	20
590+00	-1.0	-5.1	-5.1	41
600+00	-1.5	-2.1	-2.1	17
610+00	-2.5	1.4	-2.5	20
620+00	-1.0	-0.8	-1.0	8
630+00	-2.0	-2.8	-2.8	23
640+00	-2.0	-2.0	-2.0	16
650+00	-3.0	-0.1	-3.0	24
660+00	-2.5	-0.9	-2.5	20
670+00	-4.0	1.5	-4.0	32
680+00	-1.5	-2.7	-2.7	22
690+00	-3.0	0.9	-3.0	24
700+00	-3.5	3.5	-3.5	28
710+00	-1.0	-2.0	-2.0	16
720+00	-2.5	-4.1	-4.1	33
730+00	-4.9	0.0	-4.9	39
740+00	-4.0	1.1	-4.0	32
750+00	-1.5	-1.9	-1.9	15
760+00	0.0	-4.1	-4.1	33
770+00	-2.0	-2.0	-2.0	16
780+00	-3.5	1.6	-3.5	28
Average Additional Beach Width Required for 8-Year Interim Period =				**24**

Storm Erosion

While the argument could be made that the long-term shoreline change rates include the impacts of coastal storms, since the interim period for the South Section is only 8-years, recovery of storm induced erosion losses would likely not occur in such a short period of time. As noted above, the beach along the South Section of North Topsail Beach appears to still be in a storm recovery mode following the storms that impacted the area between 1996 and 1999. Accordingly, the interim fill would include an additional volume necessary to offset estimated storm induced losses during the 8-year interim period.

Storm erosion volumes applicable to the South Section were obtained from the results of the SBEACH analysis discussed above. The volumetric erosions for each of the 37 storms included in the analysis were ranked and a storm frequency curve constructed through the data points. The computed erosion volumes and a best-fit trendline through the data points are shown in Figure 81.

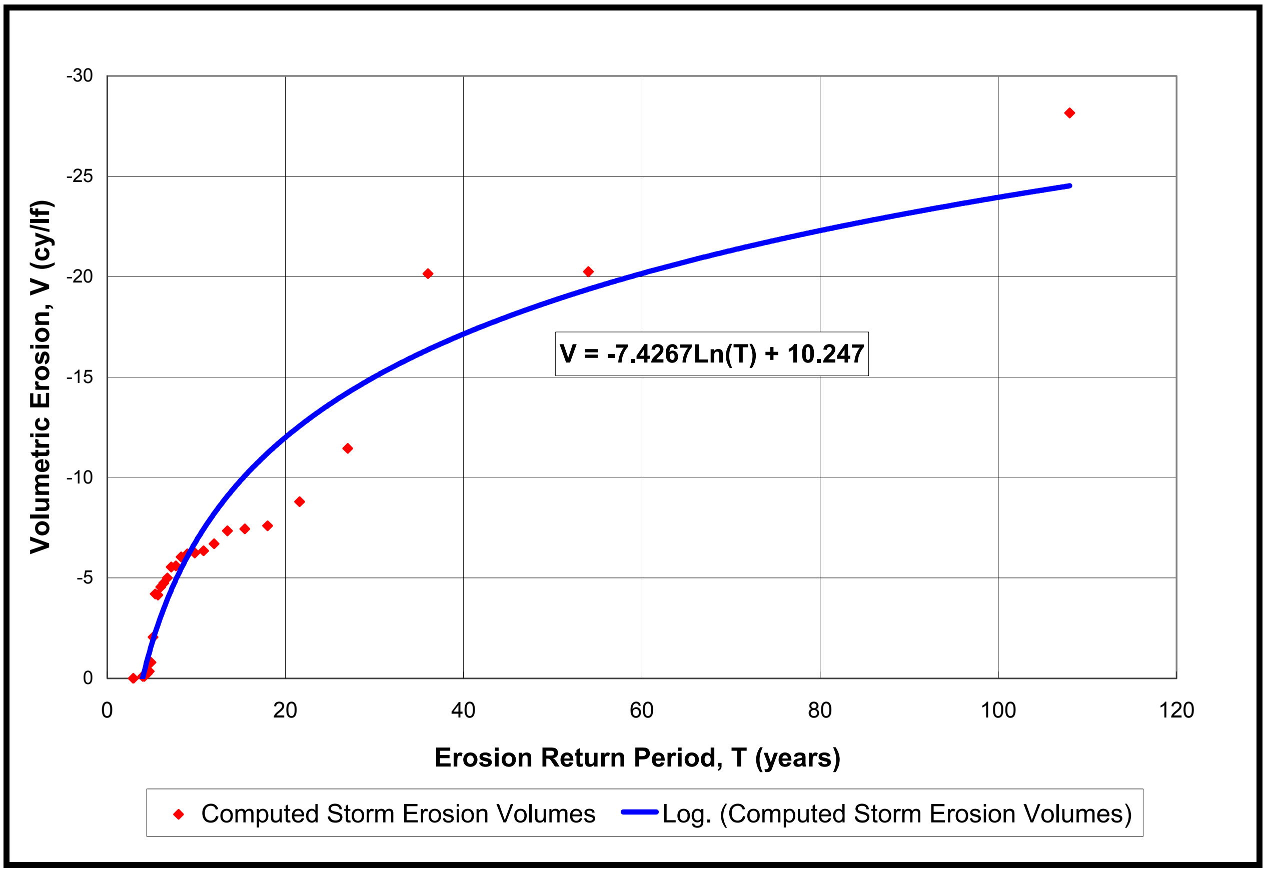


Figure 81. Frequency of storm erosion volumes for the South Section of North Topsail Beach.

The trendline defined in Figure 81 was used to compute volumetric erosion for storm return intervals (T) ranging from 2 years to 100 years. The computed values are given in Table 22.

Since the likelihood of all of these storms impacting North Topsail Beach during the 8-year interim period is rather low, the storm erosion volume that could impact the area was based on the risk that a particular storm could occur during the 8-year period.

The risk (R) that a particular event with a return period T (years) would occur during the 8-year interim period is defined by the following:

$$R = 1-(1-P)^n$$

Where: R = Risk
P = Storm probability = 1/T
n = Time period (n=8 in this case)

The risk of storms with various return intervals occurring during the 8-year interim period is also provided in Table 22.

Table 22. Probability and risk of storm volumetric erosion during the 8-year interim period.

Erosion Return Interval (T) Years	Erosion Probability (P)	Volumetric Erosion from SBEACH (cy/lf)	Risk (R)
100	0.010	-24.0	0.077
90	0.011	-23.2	0.086
80	0.013	-22.3	0.096
70	0.014	-21.3	0.109
60	0.017	-20.2	0.126
50	0.020	-18.8	0.149
40	0.025	-17.1	0.183
30	0.033	-15.0	0.238
25	0.040	-13.7	0.279
20	0.050	-12.0	0.337
15	0.067	-9.9	0.424
10	0.100	-6.9	0.570
5	0.200	-1.7	0.832
2	0.500	-0.5	0.996
Cumulative Storm Volumetric Erosion During 5-Year Interim Period			

A curve of risk versus storm erosion was constructed, as shown in (Figure 82), and the area under the curve integrated to obtain an estimate of the risk of storm erosion during the 8-year interim period.

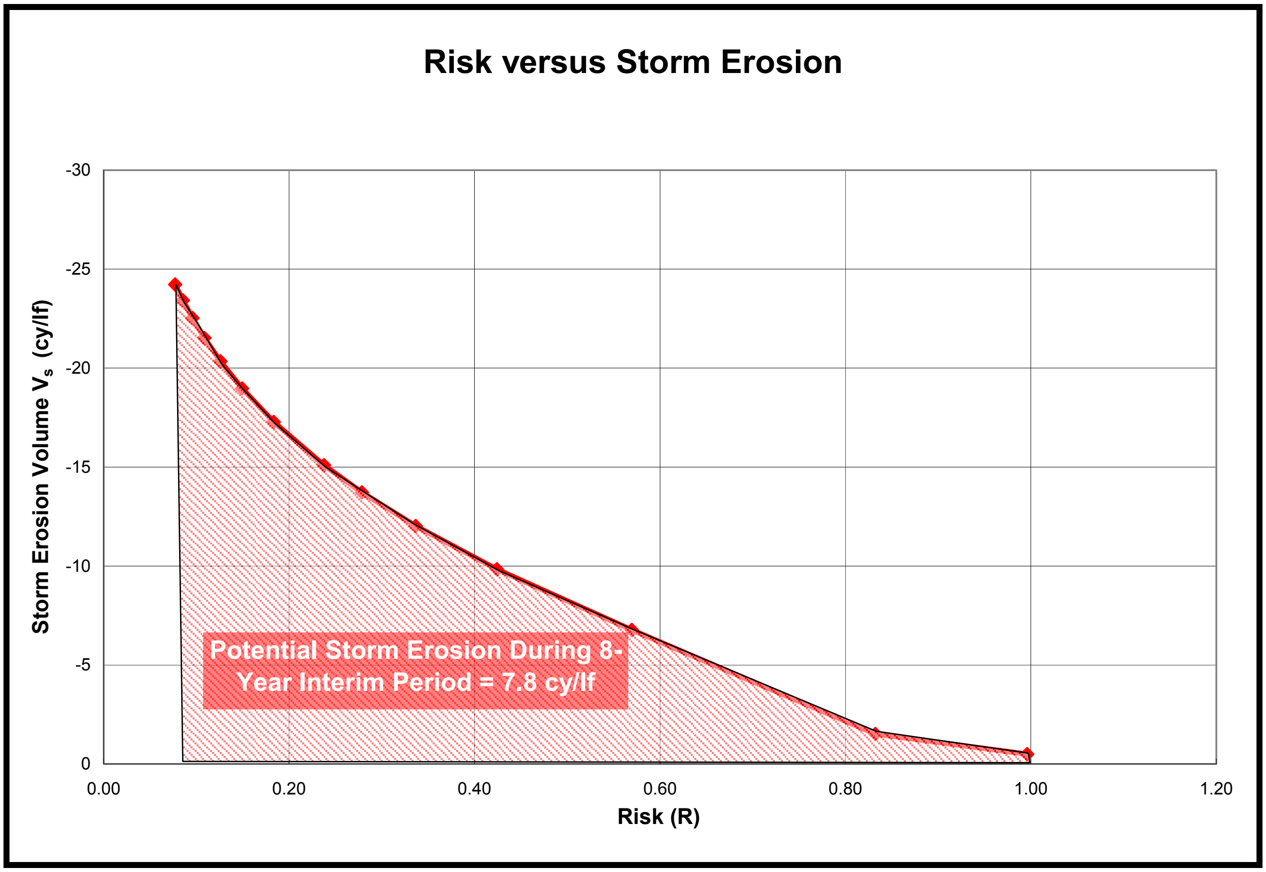


Figure 82. Storm volumetric erosion versus risk during 8-year interim period.

The area under the risk versus storm erosion volume is equal to 7.8 cubic yards/lineal foot. Thus, the volume of material needed to counter possible storm erosion in the South Section totals 160,000 cubic yards. Note that the 7.8 cubic yards/lineal foot of storm erosion associated with the risk of all storms with return periods from 2 to 100 years is approximately equal to the erosion volume for a storm with a return interval of between 10 and 15 years.

Total Interim Fill Requirement – South Section

The total interim fill requirements for the South Section includes the volume needed to address long-term shoreline changes (500,000 cubic yards) plus the volume to counter the cumulative effects of coastal storms (160,000 cubic yards) or 660,000 cubic yards in place. The total fill requirement for the South Section was reduced by 154,000 cubic yards, the volumetric accretion that occurred between March 2002 and October 2006, resulting in a total in place fill volume of 506,000 cubic yards.

Beach Fill Design Volumes

A design fill template was created for the South Section for a single +6 ft NAVD berm with a 1V:15H offshore slope, and a fill density limit of 25 cubic yards per lineal foot. A summary of the beach fill volumes is shown in Table 23. The total volume for the South Section fill is 515,400 cubic yards, including the 1,000 foot southern taper section from 571+80 to 581+80, and the taper section from 780+00 into the Central design fill at profile 785+00. An example cross-section of the South Section design fill can be seen in Figure 83. The average berm crest width is 82 feet, which varies along the length of the South Section to accommodate the 25 cubic yards per lineal foot at each profile.

Table 23: Volume Summary for South Section Design Fill

Profile Line	Fill Length (ft)	Beach Fill Volume (CY)				Source of Beach Fill
		Berm	Dune	Inlet Induced Erosion Advanced Nourishment	Total	
581+80	920	18,600	0	0	18,600	Offshore Mix
590+00	1,000	25,000	0	0	25,000	Offshore Mix
600+00	1,000	25,000	0	0	25,000	Offshore Mix
610+00	1,000	25,000	0	0	25,000	Offshore Mix
620+00	1,000	25,000	0	0	25,000	Offshore Mix
630+00	1,000	25,000	0	0	25,000	Offshore Mix
640+00	1,000	25,000	0	0	25,000	Offshore Mix
650+00	1,000	25,000	0	0	25,000	Offshore Mix
660+00	1,000	25,000	0	0	25,000	Offshore Mix
670+00	1,000	25,000	0	0	25,000	Offshore Mix
680+00	1,000	25,000	0	0	25,000	Offshore Mix
690+00	1,000	25,000	0	0	25,000	Offshore Mix
700+00	1,000	25,000	0	0	25,000	Offshore Mix
710+00	1,000	25,000	0	0	25,000	Offshore Mix
720+00	1,000	25,000	0	0	25,000	Offshore Mix
730+00	1,000	25,000	0	0	25,000	Offshore Mix
740+00	1,000	25,000	0	0	25,000	Offshore Mix
750+00	1,000	25,000	0	0	25,000	Offshore Mix
760+00	1,000	25,000	0	0	25,000	Offshore Mix
770+00	1,000	25,000	0	0	25,000	Offshore Mix
780+00	500	18,800	0	0	18,800	Offshore Mix

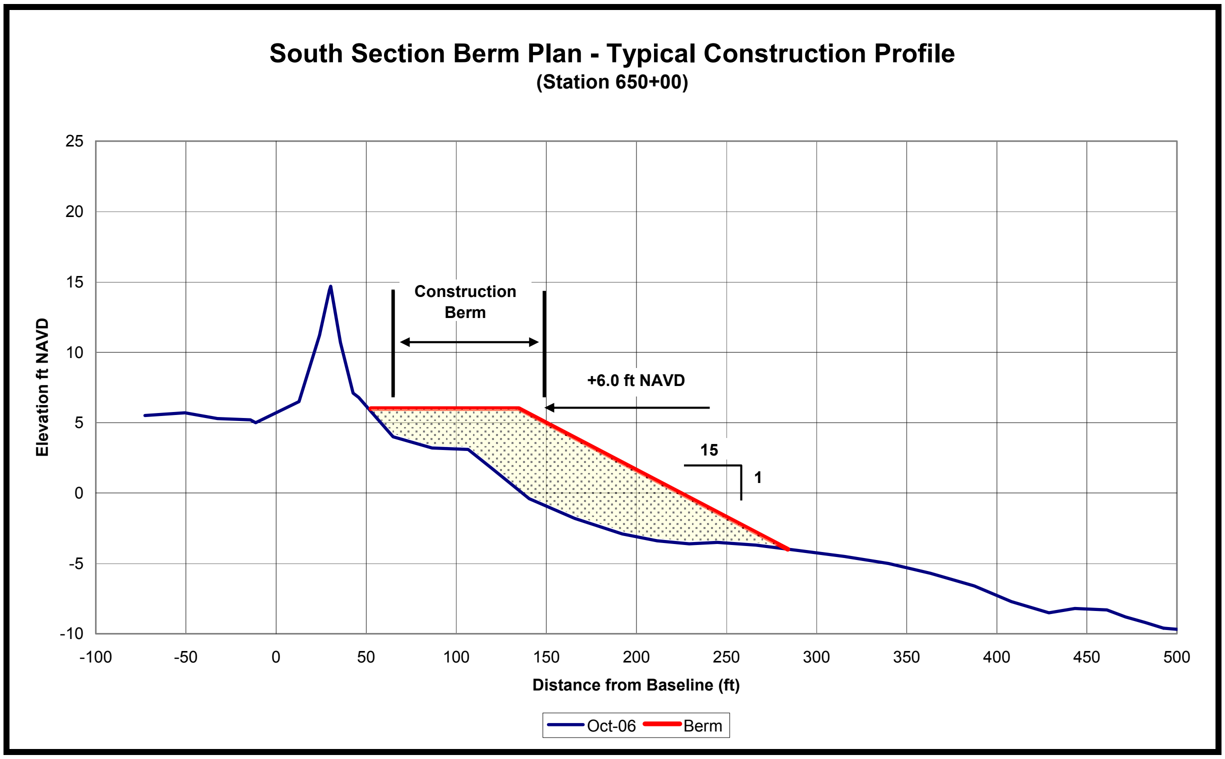


Figure 83. Example Cross-Section for South Section Design Fill at station 650+00.

Point of Intercept and Nearshore Hardbottom

The point of intercept for the South Section was calculated using the same translated profile Coastal Engineering Manual theory as the North and Central Sections. The South Section point of intercept was estimated from the October 2006 beach profile survey. The average ratio between the "theoretical" and "perched beach" A-factor (A_{rp}/A) for three areas of the South Section is summarized in Table 24.

Table 24. Perched beach A-Factor ratio, North Topsail Beach, NC

Profile Lines	A_{rp} / A
580+00 to 620+00	1.28
630+00 to 700+00	1.23
710+00 to 780+00	1.26

The source of beach fill material designated to the South Section of fill was based on fill availability and minimizing impacts to the nearshore hardbottom. Coarse fill material from the offshore borrow area is limited, and was only given to section in the North and Central fill for profiles where the distance from the baseline to the hardbottom was less than 1,000 feet. In the South Section the closest point that the nearshore gets to the baseline, is at profile 730+00, which is 1,520 feet. It is therefore unnecessary to use the coarse fill material for the South Section fill and the instead, the offshore borrow area mix fill material will be used. Table 25 below summarizes the distance from the hardbottom to the baseline at each profile from 581+00 to 780+00, along with the distance from the baseline to the Point of Intercept. The design fill planview layout for the South Section is shown in Figure 84.

Profile Station	Distance to Hardbottom from Baseline	Distance to Point of Intercept from Baseline	Source/Type of Beach Fill Material
581+80	NA	340	Offshore Mix
590+00	NA	460	Offshore Mix
600+00	NA	290	Offshore Mix
610+00	NA	280	Offshore Mix
620+00	NA	260	Offshore Mix
630+00	NA	280	Offshore Mix
640+00	NA	300	Offshore Mix
650+00	NA	320	Offshore Mix
660+00	NA	440	Offshore Mix
670+00	NA	470	Offshore Mix
680+00	NA	560	Offshore Mix
690+00	NA	480	Offshore Mix
700+00	NA	470	Offshore Mix
710+00	NA	340	Offshore Mix
720+00	NA	330	Offshore Mix
730+00	1520	340	Offshore Mix
740+00	NA	320	Offshore Mix
750+00	NA	350	Offshore Mix
760+00	2050	390	Offshore Mix
770+00	NA	540	Offshore Mix
780+00	NA	600	Offshore Mix

The total offshore borrow area mix material required for the South Section from 581+80 to 780+00 is 512,400 cubic yards, which brings the total offshore mix material to 1,939,400 cubic yards. There is 6,551,000 cubic yards available in the borrow area, which is sufficient to construct the proposed project. The total fill volume including all three types of fill material is 2,840,800 cubic yards for the entire project length.

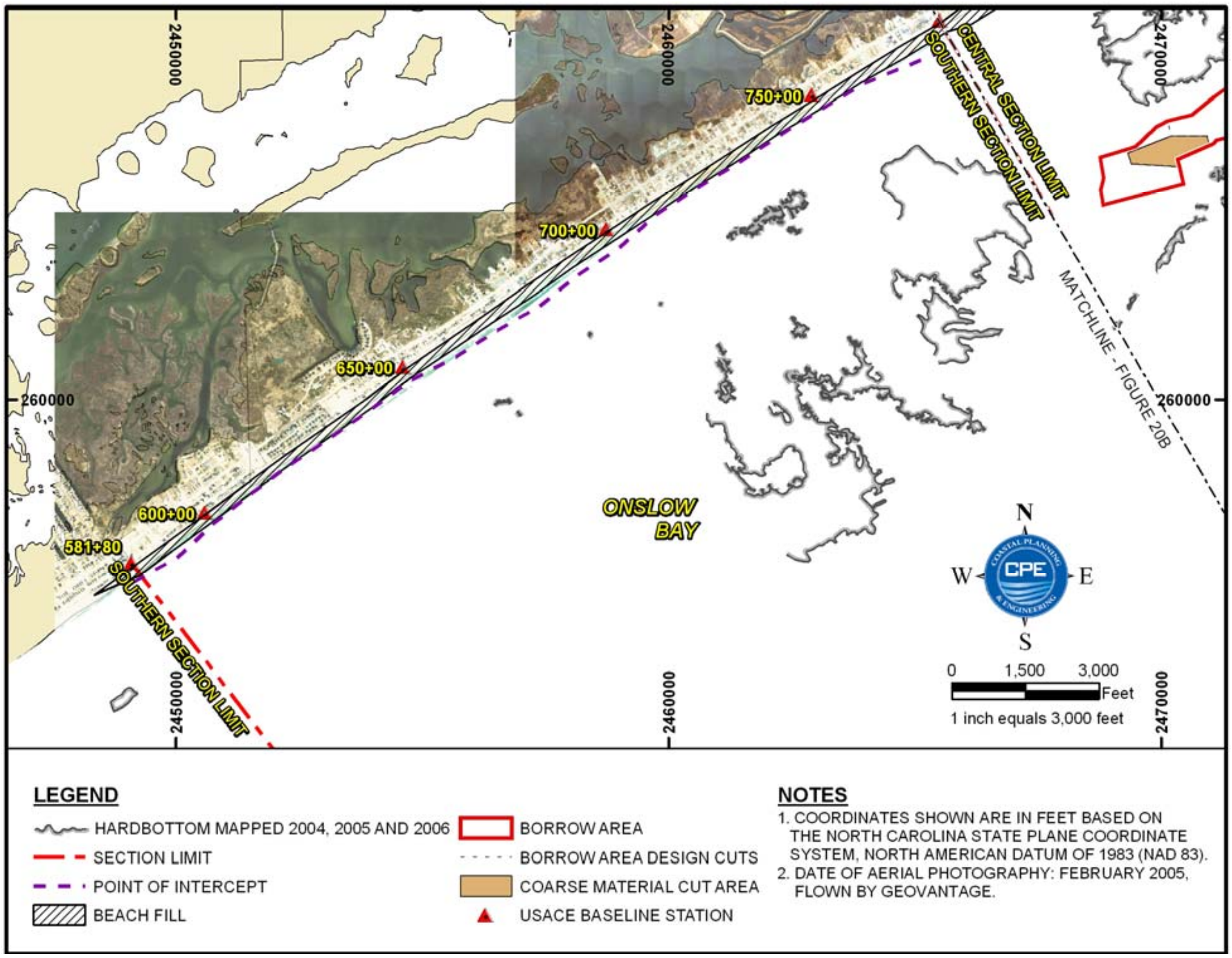


Figure 84. Beach Fill Plan - South Section

OCEAN SHORELINE AND INLET MANAGEMENT ALTERNATIVES

Introduction

The Project Delivery Team (PDT) developed seven alternatives to be evaluated for North Topsail Beach. Two of the alternatives, No Action and Buy-Out, were included as shoreline management options that would not include any artificial means of protecting the Town's tax base and infrastructure other than temporary sandbags. The No Action Alternative also provides the basis on which to measure the effectiveness of the other alternatives in satisfying the stated purposes of the project which are to preserve the Town's tax base and infrastructure and maintain its tourist oriented economy.

Four alternatives involved various combinations of beach fill and/or inlet management options that would provide varying degrees of protection. The seventh alternative, a terminal groin on the south side of New River Inlet, would address the erosion problems immediately south of the inlet but would not provide any protection for the majority of the Town's shoreline. An evaluation of the seven alternatives follows.

Alternative 1 – No Action Alternative

The economic impact of the No Action Alternative was evaluated in previous sections to aid in the selection of the size of the beach fill that would meet the project goals and objectives. The basic premise of the No Action Alternative is that the Town of North Topsail Beach and its property owners would continue to respond to erosion and storm related problems as they have in the past, namely, temporary sandbag revetments to protect threatened buildings and infrastructure followed by the eventual relocation or demolition of the threatened structures.

As presented above, the continuation of this erosion response alternative over the next 30 years would result in significant economic loss to the Town, County, and State in the form of reduced revenues from ad valorem, room occupancy, and sales taxes. Individual property owners would also experience substantial economic losses associated with the cost of either moving or abandoning their threaten buildings. Continuation of the past erosion trends would also necessitate the relocation of an 8,000-foot section of New River Inlet Road, located along the northern reaches of the Town, in approximately 20 years. Relocation of this section of the road could be required sooner should the area be impacted by a moderate to severe coastal storm in the next 10 years. With regard to storm damages, the existing condition of the beach puts a large number of oceanfront structures at a high risk for damage and possibly total destruction.

The greatest negative impacts of the No Action Alternative on the local economy would be realized from damages caused by a continuation of past shoreline erosion and the impacts of coastal storms ($23.2 million/year – Table 11, a loss of rental property and the associated reduction in rental income ($4.2 million/year – Table 13), and a reduction in local spending by vacationers and permanent residents displaced as a result of the loss of their primary residence ($5.6 million/year – Table 13). The average annual economic impact of these losses over the 30-year evaluation period totals $33.3 million/year for the Central and North Sections.

The loss of structures over the 30-year analysis period would result in a $366,100/year reduction in ad valorem tax revenues for the Town and County (Table 13). Room accommodation tax revenues would also be reduced by an average of $254,600/year while sales tax revenues would be reduced by $395,200/year (Table 13).

Alternative 2 – Buy-Out Alternative

The Buy-Out Alternative is similar to the No Action Alternative except temporary sand bag revetments would not be used to protect threatened structures. Accordingly, once a structure becomes threatened by long-term erosion, the structure would be moved to a new lot, moved back on its existing lot, or demolished. The number of structures that would be impacted under the Buy-Out Alternative would be the same as with the No Action Alternative. The major differences between the No Action Alternative and the Buy-Out Alternative would be the elimination of sand bag costs and the time when some action regarding the threatened structures would have to be taken. In this regard, the sand bag revetments were assumed to prolong the life of structures with less than 5,000 sq. ft. of floor space by 2 years and 5 years for structures with a floor space greater than 5,000 sq. ft. Accordingly, under the Buy-Out Alternative relocation and/or demolition of threatened structures would occur 2 to 5 years earlier than under the No Action Alternative.

As was the case for the No Action Alternative, the section of New River Inlet Road located between baseline stations 1010+00 and 1080+00 (Reaches 101 and 108) would be protected with sand bag revetments until year 20 at which time the road would be relocated. Failure to maintain this section of New River Inlet Road would result in the cutoff of land access to the northern portions of the Town which would essentially result in the complete abandonment of everything north of baseline station 1070+00 (Reach 107) in year 10 and everything from baseline stations 1010+00 to 1060+00 (Reach 101 to 106) in year 15.

Comparison Economic Impacts No Action Alternative versus Buy-Out Alternative

A comparison of the economic impacts of the No Action Alternative and the Buy-Out Alternative is presented in Table 26. Erosion and storm related damages are less for the Buy-Out Alternative primarily due to the assumed demolition of the Topsail Reefs Condominiums and the Villa Capriani earlier during the 30-year analysis period. These reduced structural impacts for the Buy-Out Alternative would be offset by the higher losses associated with reduced rental income and household spending. Also, the reduction in all tax revenues, including Town and County ad valorem taxes, room accommodation taxes, and sales taxes would be about 50% greater for the Buy-Out Alternative compared to the No Action Alternative.

Table 26. Comparison average annual economic impacts No Action Alternative and Buy-Out Alternative.

Economic Impact	No Action Alternative			Buy-Out Alternative		
	Central Section	North Section	Total	Central Section	North Section	Total
Damages & Losses						
Erosion & Storm Damages	$5,738,200	$17,688,400	**$23,426,600**	$5,166,900	$13,501,100	**$18,668,000**
Rental Income Loss	$529,500	$3,709,800	**$4,239,300**	$670,500	$6,144,100	**$6,814,600**
Reduction in Household Spending	$207,000	$5,437,600	**$5,644,600**	$340,000	$8,961,500	**$9,301,500**
Total Damages & Losses	**$6,474,700**	**$26,835,800**	**$33,310,500**	**$6,177,400**	**$28,606,700**	**$34,784,100**
Reduction in Tax Revenues						
Town Ad Valorem	$31,700	$115,500	$147,200	$40,400	$150,200	$190,600
County Ad Valorem	$46,900	$172,000	$218,900	$60,100	$223,900	$284,000
Sales Tax (Local & State)	$14,600	$380,600	$395,200	$24,000	$627,300	$651,300
Accommodation Tax	$31,800	$222,800	$254,600	$40,200	$368,500	$408,700
Total All Tax Revenues	**$125,000**	**$890,900**	**$1,015,900**	**$164,700**	**$1,369,900**	**$1,534,600**

Alternative 3 – Applicant's Preferred Alternative

The Applicant's Preferred Alternative includes the interim beach fill project in the South Section, a 14-foot Dune Plan in the Central and North Sections, and a management plan for New River Inlet. The interim beach fill plan for the South Section would cover 20,320 feet of the Town's ocean shoreline with a horizontal berm constructed to an elevation of +6.0 feet NAVD. The 14-foot Dune Plan would encompass a total shoreline length of 37,500 feet and would include a 1,000-foot transition on the north end next to New River Inlet. The inlet management plan involves the initial construction and periodic maintenance of a 500-foot wide x -18 ft NAVD ocean bar channel through New River Inlet. The new channel would begin in the existing inlet gorge and extend along a 155º azimuth to the -18-foot NAVD contour in the ocean.

Material for the initial construction of the 14-foot Dune Plan in the Central and North Sections would be derived from the offshore borrow area and the new inlet channel with coarse material from these two sources deposited in areas where hardbottoms are situated close to the shoreline. Construction of the interim fill along the South Section would use material from the offshore borrow area. Periodic dredging of the new bar channel in New River Inlet would be required to maintain the position, alignment, and dimensions of the channel with the material removed during the maintenance operations used to nourish the beach fill in the North and Central Sections. The volume of material that would be removed from the new channel every 4 years appears to be sufficient to maintain the beach fill in both sections; however, if the channel maintenance material is insufficient to maintain the beach fill, supplement nourishment material would be obtained from the offshore borrow area.

The 14-foot Dune Plan combined with the predicted recovery of the shoreline between baseline stations 1035+00 and 1165+00 (Reaches 114 to 116) associated with the new channel position and alignment has the potential to reduce storm and long-term erosion damages in both the

Central and North Sections by $15,160,600/year compared to the No Action Alternative. Due to the uncertainties associated with the eventual recovery of the shoreline along the extreme north end of North Topsail Beach, additional advanced nourishment totaling 109,100 cubic yards would be placed between baseline stations 1080+00 and 1160+00. A reach-by-reach summary of the reduction in storm and erosion damages for Alternative 3 is provided in Table 27.

Table 27. Summary of storm and erosion damage reduction in each Reach with Alternative 3.

Reach	Storm & Erosion Damages for: No Action Alternative	Storm & Erosion Damages for: Alternative 3	Difference in Storm & Erosion Damages No Action vs. Alternative 3[(1)]
79	$56,800	$30,200	$26,600
80	$226,000	$23,800	$202,200
81	$13,600	$0	$13,600
82	$163,100	$16,200	$146,900
83	$248,000	$135,400	$112,600
84	$146,600	$30,300	$116,300
85	$409,000	$168,000	$241,000
86	$1,272,500	$479,100	$793,400
87	$329,400	$193,500	$135,900
88	$607,300	$169,600	$437,700
89	$567,300	$127,700	$439,600
90	$34,600	$0	$34,600
91	$0	$0	$0
92	$784,900	$278,100	$506,800
93	$559,500	$727,200	-$167,700
94	$182,700	$93,200	$89,500
95	$136,900	$36,200	$100,700
Total Central Section	**$5,738,200**	**$2,508,500**	**$3,229,700**
96	$123,900	$0	$123,900
97	$1,593,800	$441,300	$1,152,500
98	$361,100	$5,800	$355,300
99	$77,200	$0	$77,200
100	$218,600	$404,500	-$185,900
101	$287,700	$30,500	$257,200
102	$530,000	$699,100	-$169,100
103	$260,100	$169,900	$90,200
104	$356,600	$0	$356,600
105	$563,500	$0	$563,500
106	$208,900	$0	$208,900
107	$402,400	$34,900	$367,500
108	$416,400	$13,300	$403,100
109	$771,400	$132,500	$638,900
110	$3,220,400	$747,200	$2,473,200
111	$1,551,200	$307,200	$1,244,000
112	$2,115,800	$191,400	$1,924,400
113	$571,600	$62,000	$509,600
114	$1,784,800	$1,223,300	$561,500
115	$645,500	$653,900	-$8,400
116	$1,012,400	$285,700	$726,700
Total North Section	**$13,762,400**	**$5,757,500**	**$11,930,900**
Total 79 to 113	$4,057,800	$5,748,100	$13,620,700
Total 114 to 116	$19,368,800	$2,517,900	$1,539,900
Total 79 to 116	**23,426,600**	**$8,266,000**	**$15,160,600**

[(1)] Negative values indicate potential damages in that Reach are potentially greater under Alternative 3 than under the No Action Alternative.

As indicated by the note and negative values in Table 27, potential storm and erosion damages in several reaches are greater with Alternative 3 compared to the No Action Alternative. This is primarily due to the assumption that certain structures would be moved or demolished under the No Action Alternative while all structures were assumed to remain in place with the implementation of Alternative 3. Also provided in Table 27 are totals for Reaches 79 to 113 and Reaches 114 to 116. Reference to these totals will be made later.

The Applicant's Preferred Alternative would protect the tax base in the Central and North Sections of North Topsail Beach against losses due to a continuation of long-term erosion. In so doing, the estimated losses under the No Action Alternative for income from vacation rentals and local spending and the occupancy taxes and sales taxes derived from these activities (summarized in Table 13) would be prevented. Potential tax revenue losses for the No Action Alternative that would be prevented with the Applicant's Preferred Alternative include a total of $366,100 per year in Town and County ad valorem taxes, $254,600 per year in room occupancy taxes, and $395,200 in State and local sales taxes.

The estimated costs for constructing and maintaining Alternative 3 are provided later in the Cost Estimates section of this report.

Alternative 4 – Beach Nourishment without the Inlet Management Plan

The interim beach fill plan would be constructed in the South Section while the 14-foot Dune Plan would be constructed from baseline stations 785+00 to 1160+00; however, no action would be taken to modify New River Inlet. Without the inlet management plan, the added beach width that would be provided by the 14-foot Dune Plan between baseline stations 1135+00 to 1160+00 (Reaches 114 to 116) would be around 75 to 100 feet. Based on the storm impact distances in this area for the No Action Alternative (Table 12) a beach width of 200 to 300 feet would be needed to substantially reduce storm damages. Assuming construction of the project would prevent the demolition of oceanfront structures in Reaches 114 to 116, including the Reefs Condominium, potential storm damages in these reaches would be higher compared to the No Action Alternative.

An added factor that could contribute to potentially greater storm damages would be the inability to maintain the beach fill in the northern reaches. In this regard, without the recovery of the shoreline just south of New River Inlet, sediment losses from the north end of the fill would occur at a high rate resulting in reduced beach widths between periodic nourishment operations.

The potential reduction in storm and erosion damages for the 14-foot Dune Plan could reduce potential storm and erosion damages between baseline stations 785+00 and 1135+00 (Reaches 79 to 113) by $13.62 million/year which is the same level of damage reduction associated with Alternative 3 in these reaches (Table 27). However, storm damages from baseline stations 1135+00 to 1160+00 (Reaches 114 to 116) could be $5.40 million/year greater than the No Action Alternative if all of the present structures remain in place. As a result of the potentially greater storm damages, Alternative 4 would only reduce storm and erosion damages by $8.22 million/year for the entire project area.

If all of the structures remained in place as assumed for Alternative 4, rental income and household spending would be maintained as with Alternative 3. More than likely, repeated storm damage to development in Reaches 114 to 116 could eventually result in the removal or demolition of all oceanfront structures in these areas. This would ultimately reduce rental income and household spending. On the other hand, the removal of structures from Reaches 114 to 116 would also decrease the potential for storm damages. Prediction of when or if structures would be removed from Reaches 114 to 116 under Alternative 4 were not made due to the uncertainty associated with individual decisions that would be associated with such actions.

In the absence of an inlet management plan, construction of the 14-foot Dune Plan in the areas where hardbottoms encroach close to shore would be problematic given the limited volume of coarse grain material available from the offshore borrow area. This could result in either the exclusion of some sections of the North Topsail Beach shoreline or greatly reduced beach fill design sections in the hardbottom areas.

Periodic nourishment of the beach fill project would have to be accomplished entirely from the offshore borrow area or with material from an upland source. Since construction of the project using the offshore borrow area will deplete the known source of coarse material, a new source of coarse offshore material will have to be identified in order to avoid possible impacts on the nearshore hardbottom resources.

Construction costs for Alternative 4 were also evaluated using an upland borrow source and a combination of upland borrow material and material from the offshore borrow area. These costs are presented in the Coast Estimate section of this report.

Alternative 5 – Beach Nourishment with One-Time Relocation of New River Inlet Bar Channel

The 14-foot Dune Plan in the Central and North Sections would be initially constructed using a combination of material from the offshore borrow area and the one-time relocation of the inlet bar channel. The interim plan in the South Section would also be constructed using material derived from the offshore borrow area. Subsequent periodic nourishment of the beach fill in the Central and North Sections would come from the offshore borrow area, upland sources, or a combination of offshore and upland sources.

Potential Storm Damage Reduction in Reaches 114 to 116 with Alternative 5

Construction and periodic nourishment of the 14-ft Dune Plan would provide the same level of storm and erosion damage reduction in Reaches 79 to 113 (baseline stations 785+00 to 1135+00) as described under Alternatives 3 and 4 which was equal to $13.62 million/year. However, damage reduction in Reaches 114 to 116 would fall somewhere between Alternatives 3 and 4. In this regard, the predicted shoreline recovery for Reaches 114 to 116 associated with the Inlet Management Plan depends on the repeated relocation and alignment of the bar channel during the 30-year analysis period. Without repeated maintenance, the channel would be expected to behave in a manner similar to that which occurred between 1984 and 2003, that is, the channel should gradually migrate to an orientation toward Onslow Beach. Storm and erosion damage reduction in Reaches 114 to 116 for the Applicant's Preferred Alternative (Alternative 3) was based on a 15-year recovery shoreline recovery period and the assumption that the new shoreline could be maintained through a program of periodic nourishment using the coarse grain sediment from the maintenance of the new channel in New River Inlet. Accordingly, positive shoreline changes in Reaches 114 to 116 associated with the one-time channel relocation under Alternative 4 should be relatively minor and of a short duration.

A review of the channel orientation tendencies presented in Figure 45 shows the channel moved from a southwesterly alignment in 1984 (azimuth greater than 150^o to a shore normal alignment (150^o azimuth) by 1991. If the new channel behaved in a similar manner, shoreline recovery on the north end of North Topsail Beach would probably be limited to a 5-year period after which time it would begin to erode at rates comparable to the 1984 to 2003 period. While the full recovery of the shoreline in Reaches 114 to 116 with Alternative 3 was predicted to take 15 years, if the one-time channel relocation produced positive shoreline responses for 5 years, the expected recovery in Reaches 114, 115, and 116 would be about one-third of that expected for Alternative 3. Therefore, the assumed recovery over 5 years under Alternative 5 would be 35, 60, and 70 feet, for Reaches 114, 115, and 116, respectively. Following this 5-year recovery period, these shoreline reaches would again begin to erode at the same rates observed from 1984 to 2003. Erosion rates during this period were 5.9 ft/yr, 9.4 ft/yr, and 11.6 ft/yr for Reaches 114, 115, and 116, respectively. These erosion rates would eliminate the 5-year shoreline gains in all three reaches in approximately 6 years.

Storm damage potential over the 30-year analysis period in Reaches 114 to 116 for Alternative 5 is plotted in Figure 85. Potential storm damages would decrease from \$9.5 million/year to \$4.7 million/year in year 5 and then increase back to \$9.5 million/year in year 11. The average annual equivalent of the potential storm damages in Reaches 114 to 116 equals \$8.59 million/year. Compared to the No Action Alternative, average annual damages in Reaches 114 to 116 would be reduced by \$1.86 million/year. Damage reduction for the entire project area under Alternative 5 would total \$15.48 million/year.

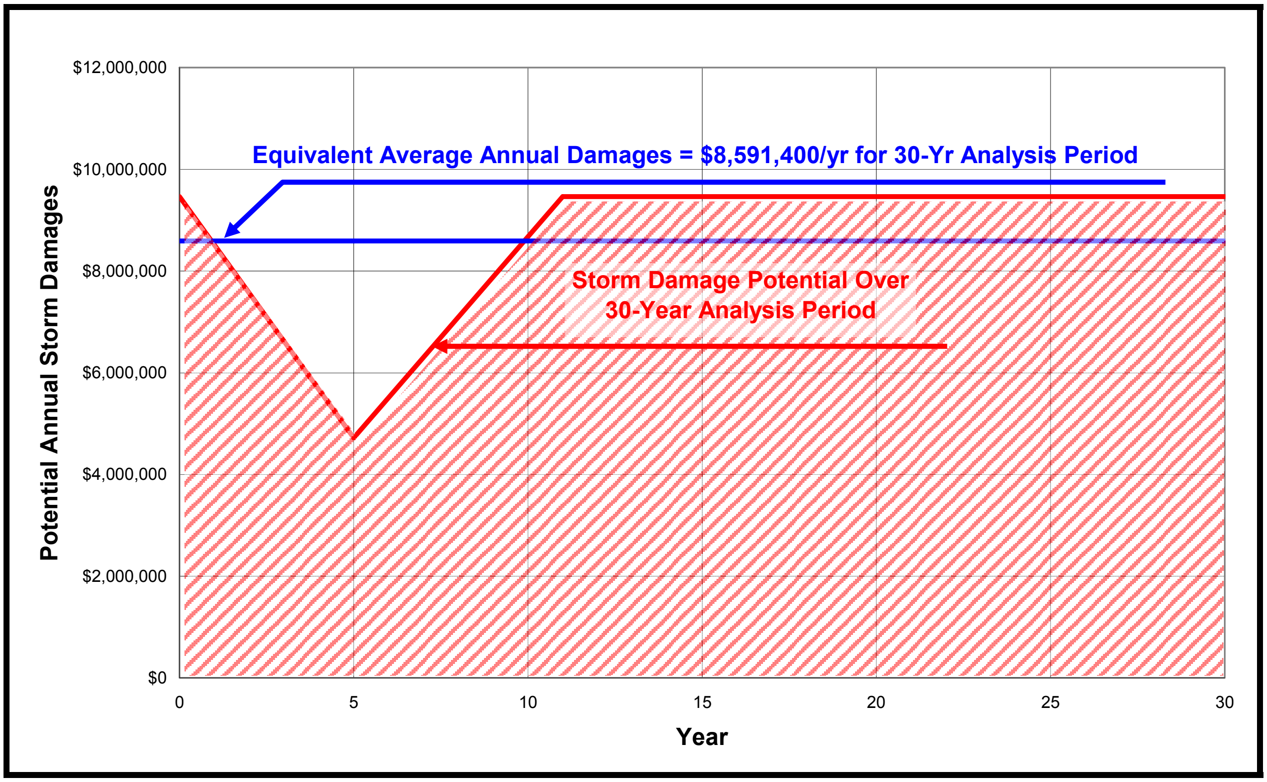


Figure 85. Annual storm damage potential in Reaches 114 to 116 (baseline stations 1135+00 to 1165+00) over the 30-year analysis period for Alternative 5.

Since inlet material would not be available to provide periodic nourishment of the beach fill, periodic nourishment material would have to come from either the offshore borrow area or an upland borrow site. With regard to the offshore borrow area, construction of the project would deplete the coarse sand resources identified in the present borrow area. Use of the remaining fine grained material in the present offshore borrow area for periodic nourishment could negatively impact nearshore hardbottom resources, therefore, a new offshore source of coarse grain borrow material would have to be identified.

Alternative 6 – Inlet Management Plan

The 500-ft wide x -18-ft NAVD channel would be constructed in the new position and along the new alignment with material removed to construct the channel and evenly distributed along the entire 37,500 feet of ocean shoreline within the Central and North Sections of North Topsail Beach. The interim plan for the South Section would still be constructed using the offshore borrow area. Material removed to periodically maintain the channel would also be evenly distributed to maintain the shoreline in the Central and North Section.

The volume of material that would be removed to construct the new channel is presently estimated to be 635,800 cubic yards based on the August 2005 survey of New River Inlet. However, as discussed previously, 91,400 cubic yards is clay and shell which would be deposited in an upland disposal site. The 544,400 cubic yards of beach compatible material would be evenly distributed along the North and Central Sections at a rate of approximately 14 cubic yards/lineal foot. The construction width of the +6.0-ft NAVD berm would be approximately 30 to 35 feet with the adjusted width equal to 10 to 15 feet.

Material for the periodic nourishment of the beach fill project would be derived from the maintenance of the new ocean bar channel in New River Inlet. Material removed to maintain the channel would also be equally distributed along the entire 37,500-foot project. The estimated rate of shoaling of the new bar channel appears to be sufficient to satisfy periodic beach fill nourishment requirements. However, if shoaling of the channel does not satisfy nourishment requirements, a source of suitable borrow material would have to be located.

Initial construction of the beach fill using the inlet channel material combined with the periodic maintenance material from the inlet appears to be adequate to counter long-term shoreline losses. Preventing long-term erosion would theoretically maintain the existing position of the shoreline over the 30-year analysis period; however, the relatively minor fill quantities would not provide any substantial storm protection. Also, by holding the shoreline in its present position, all of the oceanfront structures would presumably remain in place.

Alternative 6 would theoretically maintain the existing tax base for North Topsail Beach at the expense of increasing the storm damages to structures that were predicted to be moved or demolished under the No Action Alternative. Storm damages in the Central and North Sections would total \$43.63 million/year with Alternative 6 or \$20.20 million/year greater than the No Action Alternative.

Due to the high level of storm damage potential, relocation and/or demolition of buildings that would experience repeated storm damage is likely since most of the buildings in the Central and North Sections are not covered by flood insurance. The decision to relocate or demolish buildings subjected to repeated storm damage would be made by individual property owners based on their specific circumstances and therefore could not be factored into this analysis. In any event, negative impacts on the Town's tax base would be likely under Alternative 6.

Alternative 7 – Terminal Groin

In 2003, the State of North Carolina modified the Coastal Area Management Act of 1974 (CAMA) to prohibit the use of "hard structures" as coastal erosion response measures. Prior to the amendment, hard structures had been prohibited by rules adopted by the NC Coastal Resources Commission. During the 2007 NC Legislative Session, the Senate passed a bill that would allow the installation of an experimental terminal groin at an unspecified inlet. A terminal groin is defined as a singular structure constructed immediately adjacent to a tidal inlet which is designed to reduce shoreline erosion caused by a combination of wave and tidal current induced sediment transport. The bill would require the groin to be evaluated in an Environmental Impact Statement and approved by the Coastal Resources Commission prior to installation. The bill moved to the NC House but no action was taken prior to adjournment of the 2008 Session. A similar bill was introduced in the Senate during the 2009 Legislative Session. The bill was also passed by the Senate and is presently being considered by the House. At the time of this report (July 2009), no final decision had been reached on the proposed terminal groin legislation.

The CAMA and the pending terminal groin legislation notwithstanding, a terminal groin alternative was evaluated as a possible means of protecting development on North Topsail Beach located adjacent to the south shoulder of New River Inlet. The terminal groin option was selected over other types of hard structures, including the Holmberg Technologies, since terminal groins have been used successfully to control inlet related shoreline erosion in North Carolina at Beaufort Inlet and at Oregon Inlet.

A terminal structure on the extreme north end of North Topsail Beach would consist of a revetment along the inlet shoreline and a groin extending into the ocean (Figure 86). The total length of the terminal structure would be approximately 2,500 feet with the landward most 1,000 feet constructed as a sloping rubble revetment and the seaward 1,500 feet constructed either as a free-standing rubble mound or a single row of concrete sheet piles. The terminal groin would ostensibly create an accretion fillet that would widen and stabilize the shoreline from the inlet shoulder south to baseline station 1135+00, or a distance of 2,500 feet. Depending on the structural design of the terminal groin, construction costs could range from $7.5 to $10.0 million.

The terminal groin would be designed to facilitate the one time recovery of the shoreline without continually entrapping littoral sediment. Accordingly, the crest elevation of the groin would be +6 feet NAVD or equal to the elevation of the natural berm in the area. The length of the groin would be limited to that necessary to stabilize the 2,500 feet of shoreline to its south. With these design features, once the accretion fillet is completely formed, littoral material would be free to pass over the crest of the groin and around its seaward end, i.e., the groin would not have any long-term impacts on the movement of sediment into the New River Inlet system.

The accretion fillet that would form south of the terminal groin would vary in width from about 700 feet immediately adjacent to the groin to approximately 200 feet 1,000 feet south of the groin. The fillet would then gradually merge with the existing shoreline at a point 2,500 feet south of the groin. The total area of dry land created by the fillet would be around 15 acres with the volume of littoral sediment impounded by the groin ranging from around 150,000 to 200,000 cubic yards. The rate of littoral sediment transport moving toward New River Inlet from North Topsail Beach is estimated to be 270,000 cubic yards/year (Figure 53). Therefore, fillet formation could take less than one year after which no additional sediment accumulation would occur. Note that the littoral material trapped by the groin would be material destined to be deposited in New River Inlet, a large percentage of which remains trapped in the inlet under existing conditions.

While the terminal groin would not provide any protection for the majority of North Topsail Beach, it would allow a beach fill to be extended all the way to New River Inlet. In this regard, the terminal groin would control losses from the north end of the fill due to tidal currents flowing into the inlet as well as accelerated sediment transports rates associated with wave transformations over the inlet's ebb tide delta.

The terminal groin and the associated accretion fillet would provide substantial widening of the beach in Reaches 115 and 116 (baseline stations 1145+00 to 1165+00) and possibly stabilize the shoreline in Reach 114 (baseline stations 1135+00 to 1145+00). However, since State Law presently prevents the use of this type of structure, a detailed analysis of the economic impacts of the groin was not made.

Figure 86. Schematic of terminal groin – Alternative 7.

Summary Economic Impacts of Alternatives

Damages due to long-term erosion, which includes the cost of relocating or demolishing threatened structures, and the associated losses in household spending and rental income were assumed to be negligible for Alternatives 3 to 6; therefore, the primary difference in the economic impact of these alternatives is attributed to the level of storm and erosion damage prevention each alternative would provide. Storm and erosion damages for each of the alternatives are summarized in the top half of Table 28 while the bottom half of the table gives the difference in average annual storm and erosion damages for the alternative compared to the No Action Alternative.

Table 28. Comparison of average annual storm and erosion damages for the shoreline and inlet management alternatives in the Central and North Sections of North Topsail Beach, NC.

Alternative	**Storm & Erosion Damages (Million $/year)**		
	Central Section	**North Section**	**Total**
Alternative 1 – No Action	$5.74	$17.69	$23.43
Alternative 2 – Buy-Out	$5.17	$13.50	$18.67
Alternative 3 – Applicant's Preferred	$2.51	$5.76	$8.27
Alternative 4 – 14-Ft Dune; No Inlet Mgmt.	$2.51	$12.70	$15.21
Alternative 5 – 14-Ft Dune; One-Time Channel	$2.51	$11.83	$14.34
Alternative 6 – Inlet Management Only	$9.54	$34.09	$43.63
Alternative 7 – Terminal Groin	**…….…....Not Evaluated……….**		
Alternative	**Damage Difference – No Action vs. Alternatives [1] (Million $/year)**		
Alternative 1 – No Action	-----	-----	-----
Alternative 2 – Buy-Out	$0.57	$4.19	$4.76
Alternative 3 – Applicant's Preferred	$3.23	$11.93	$15.16
Alternative 4 – 14-Ft Dune; No Inlet Mgmt.	$3.23	$4.99	$8.22
Alternative 5 – 14-Ft Dune; One-Time Channel	$3.23	$5.86	$9.09
Alternative 6 – Inlet Management Only	-$3.80	-$16.40	-$20.20
Alternative 7 – Terminal Groin	**…….…....Not Evaluated……….**		

(1) Negative values indicate storm and erosion damages greater than No Action Alternative.

As discussed previously, the equivalent average annual storm and erosion damages for the Buy-Out Alternative would be less than the No Action Alternative due to the assumption that no sandbags would be used to temporarily protect threatened structures. As a result of this assumption, threatened structures would be relocated landward or demolished earlier in the 30-year analysis period compared to the No Action Alternative resulting in less storm damage. However, as shown in Table 26, the Buy-Out Alternative would have a greater negative impact on rental income and household spending compared to the No Action Alternative due to the earlier relocation or demolition of threatened structures.

Alternatives 3 to 5 would provide the same level of storm and erosion protection in the Central Section with damage levels differing in the North Section depending on the actions taken to manage New River Inlet. Alternative 6, which would only include management of the bar channel in New River Inlet, would not provide any substantial storm protection in either the Central or North Section. Based on the assumption that all structures would remain in place with Alternative 6, storm damages are actually greater for this alternative compared to the No Action Alternative. If Alternative 6 was implemented, repeated storm damages to oceanfront structures would more than likely result in their eventual relocation or demolition.

Sediment Budget with Applicant's Preferred Alternative – Alternative 3

The existing sediment budget for New River Inlet and the adjacent islands presented in Figure 52 indicates that New River Inlet removes a total of 130,000 cubic yards/year from the littoral system. This total includes 101,000 cubic yards/year trapped on the ebb tide delta and in Cedar Bush Cut with an additional 29,000 cubic yards/year removed from the inlet by the Corps of Engineers mini-hopper dredge CURRITUCK. Shoaling of the larger channel across the ocean bar of New River Inlet that would be constructed as part of the Applicant's Preferred Alternative would trap an estimated 627,000 cubic yards every 4 years. Shoaling in Cedar Bush Cut should continue at its historic rate which has resulted in the average removal of 48,000 cubic yards/year by the Corps of Engineers since 1978. Thus, over a 4-year period, Cedar Bush Cut would accumulate approximately 192,000 cubic yards.

The combined shoaling of the new bar channel and shoaling in Cedar Bush Cut every 4 years would total 819,000 cubic yards or an average of about 205,000 cubic yards/year. In the absence of artificial bypassing of sediment around the inlet, the entrapment rate in the New River Inlet complex would increase by 75,000 cubic yards/year over existing conditions. The increased rate of entrapment in the inlet was assumed to reduce natural sediment bypassing around the inlet by an equal amount. The allocation of this reduced natural bypassing to Onslow Beach and North Topsail Beach was based on the distribution of natural sediment bypassing under existing conditions. Presently, a total of 604,000 cubic yards/year bypassing New River Inlet with 193,000 cubic yards/year moving onto Onslow Beach and 411,000 cubic yards/year deposited on North Topsail Beach (Figure 51). For the inlet management plan, natural sediment bypassing would be reduced by 75,000 cubic yards/year from 604,000 cubic yards/year to 529,000 cubic yards/year. The natural bypassing of this volume of material past New River Inlet and onto the adjacent beaches was assumed to occur in the same ratios as under existing conditions. Based on this assumption, the volume of material that would naturally bypass New River Inlet toward Onslow Beach with the inlet management plan would be 169,000 cubic yards/year {=(193,000cy/yr/604,000cy/yr) x 529,000cy/yr} with natural bypassing to North Topsail Beach equal to 360,000 cubic yards/year.

Maintenance of the new channel in New River Inlet would be necessary to keep the channel in its new location; therefore, regardless of the beach nourishment requirements, all of the material that accumulates in the new channel would have to be removed. While there have been recent issues with federal funding for small navigation projects, the Corps of Engineers maintenance dredging in Cedar Bush Cut with disposal on the northernmost 5,000 feet of North Topsail Beach would presumably continue. As noted above, the combination of these two operations could result in the deposition of an estimated 819,000 cubic yards on North Topsail Beach every 4 years. Since periodic nourishment of the beach fill in the Central and North Sections would require 584,000 cubic yards every 4 years (146,000 cubic yards/year), the volume of material that would be removed from the New River Inlet complex should more than satisfy periodic beach nourishment requirements.

The sediment budget for the inlet management plan, which includes the transfer of an average of 205,000 cubic yards/year to North Topsail Beach and the modified natural sediment bypassing discussed above, is shown in Figure 87.

The sediment budget with the inlet management plan would, in the absence of artificial bypassing of sediment from the inlet to Onslow Beach, increase the deficit on the south end of Onslow Beach from 97,000 cubic yards/year to 121,000 cubic yards/year (Figure 87). The original plan developed in the Feasibility Report (CPE-NC, 2002), included the placement of material from New River Inlet on the south end of Onslow Beach during initial construction of the channel and subsequent periodic disposal to maintain the existing sediment budget on Onslow Beach. However, coordination with the US Marine Corps, which owns Onslow Beach, the NC Wildlife Resources Commission, and the US Fish and Wildlife Service indicated that the disposal of material on Onslow Beach would not be consistent with its recently developed Integrated Natural Resource Management Plan (INRMP). The INRMP identified the overwash areas on the south end of Onslow Beach as a prime habitat for piping plover and other shore birds. These agencies were not in favor of nourishing this section of the island due to possible reductions in overwash episodes. Given the relatively small impact predicted for the sediment budget on Onslow Beach associated with the inlet management plan, the US Marine Corps favored a beach monitoring plan for the island in lieu of mitigation beach fills. If the monitoring surveys reveal significant impacts, mitigative measures would be developed with the Marine Corps working in cooperation with the NC Wildlife Resources Commission and the U.S. Fish and Wildlife Service.

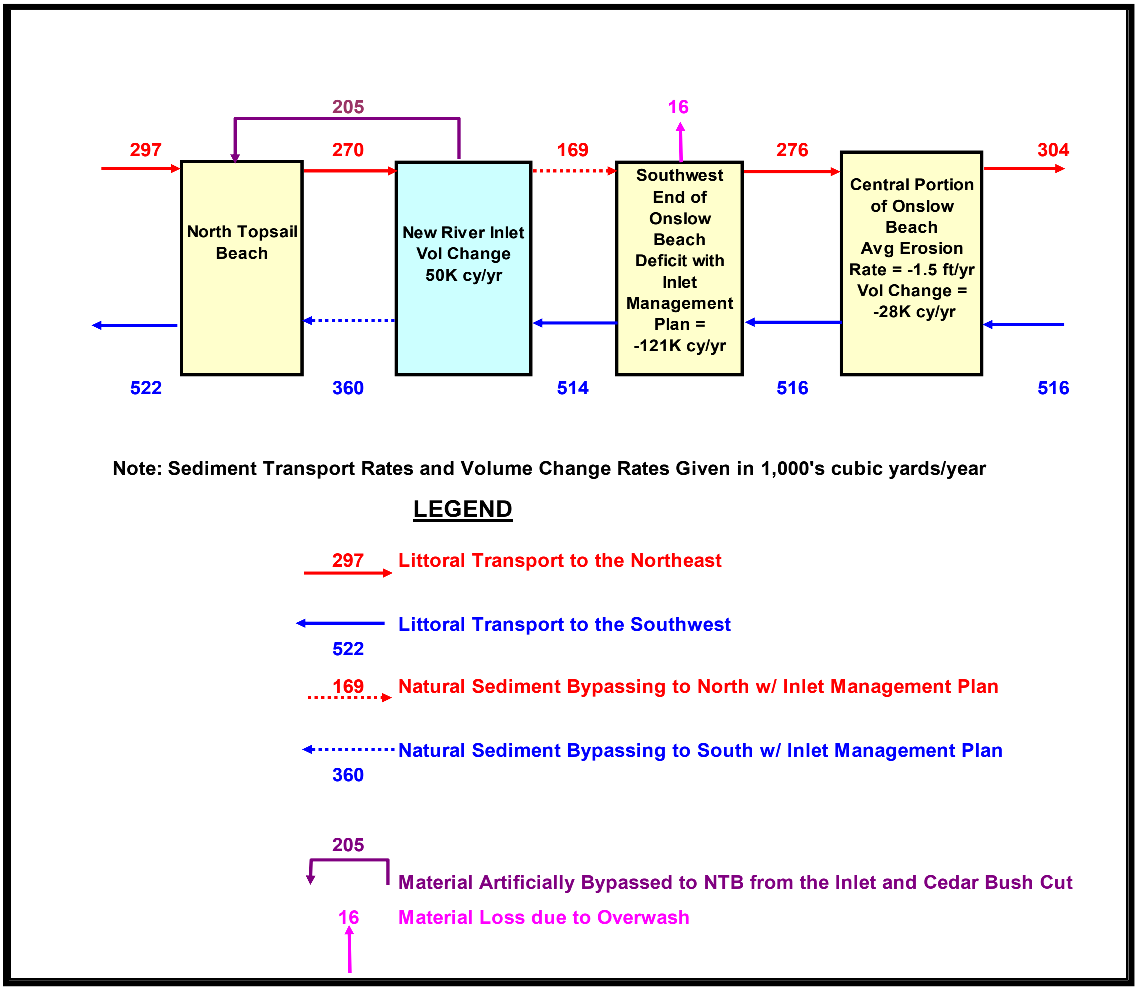


Figure 87. Sediment budget for New River Inlet with inlet management plan.

Implementation of the Applicant's Preferred Alternative would not completely deplete sediment accumulation within the inlet complex, which could be important to the maintenance of shallow bottom habitats and subaerial shoals. Based on the sediment budget presented in Figure 87, the inlet complex would accumulate an average of 50,000 cubic yards/year if 205,000 cubic yards/year is removed from the inlet complex and deposited on North Topsail Beach.

COST ESTIMATES

Alternative 3 – Applicant's Preferred Alternative

Initial Construction – Alternative 3

The Town of North Topsail Beach proposes to construct the project in 5 phases based on its anticipated funding stream. The first phase of construction would occur between 16 November 2010 and 31 March 2011 (environmental dredging window) and would involve the relocation of the New River Inlet channel. Material from the channel relocation would be used to construct 9,000 feet of the beach fill from baseline station 1160+00, located next to New River Inlet, to 1070+00. Phase II would occur during the November 2012 to March 2013 dredging window and would cover 10,120 feet of shoreline between baseline stations 968+80 to 1070+00. Material for Phase II would come from the offshore borrow area. Coarse material from the offshore borrow area would be placed between baseline stations 1020+00 and 1070+00 (nearshore hardbottom areas) with the balance of the area constructed with material from the northeast portion of the borrow area.

Phase III would be scheduled for the November 2014 to March 2015 dredging window or 4 years after the initial channel relocation and would cover the shoreline between baseline stations 785+00 and 900+00. This is an area that includes hardbottoms relatively close to shore and would be constructed using coarse material from either the offshore borrow area or coarse shoal material removed to reestablish the position and alignment of the inlet bar channel. Based on shoaling predictions in the new channel, the 85% shoaling threshold would be exceeded within the first four years following channel relocation which would trigger the first channel maintenance operation. Assuming the 4-year shoal predictions are correct (predicted shoal volume = 627,000 cubic yards), the volume of shoal material that would have to be removed to reestablish the channel would be sufficient to initially construct the beach fill in Phase III and provide periodic nourishment for the beach fill constructed during Phase I. Accordingly, the costs for Phase III were based on using material from maintenance of the New River Inlet ocean bar channel. The volume of material not needed to construct Phase III would be equally distributed along the shoreline covered by Phase I.

Phase IV, which would be scheduled for the 2016 to 2017 environmental dredging window, would be constructed using material from the offshore borrow area and would cover the shoreline north of station 900+00 to 968+00. Phase IV would complete the beach fill within the North and Central Sections of North Topsail Beach. Construction of Phase IV would also correspond to the time nourishment could be required along the Phase II shoreline (968+80 to 1070+00). Since channel maintenance would not be scheduled at this time, nourishment of Phase II would be accomplished using coarse material from the offshore borrow area.

Phase V, the final initial construction phase, would occur during the 2018 to 2019 environmental dredging window and would provide an interim beach fill along the southern 20,320 feet of the town's shoreline. Phase V would also be constructed using material from the offshore borrow area.

Construction of Phase V would be scheduled 8 years after initial construction of the new bar channel in New River Inlet and, based on the theoretical shoaling predictions, could occur at the same time maintenance of the new channel is required. By this time, all or portions of the shoreline segments constructed during Phases I to IV would be in need of periodic nourishment, therefore, the inlet channel maintenance material could be deposited between the inlet and baseline station 785+00. The exact location of disposal would depend on the performance of the fill placed in the four segments, however; for cost estimating purposes, the channel maintenance material is assumed to be equally distributed along the entire 37,500 feet of shoreline associated with Phases I to IV.

A summary of the phased construction costs for Alternative 3 is provided in Table 29.

Table 29. Cost Estimates for Phased Construction of Alternative 3, the Applicant's Preferred Alternative.

Item	Unit	Quantity	Unit Cost	Cost
Phase I: Inlet Channel (1070+00 to 1160+00)				
Mob & Demob	Job	1	Lump Sum	$1,666,000
Dredging (1070+00 to 1160+00)				
Beach Fill (1070+00 to 1160+00)	CY	544,400	$4.21	$2,292,000
Upland Disposal	CY	91,400	$4.21	$385,000
Additional pipe mob & demob + dike and outfall structure	Job	1	Lump Sum	$400,000
Sub Total - Phase I				$4,743,000
Contingency (15%)				$711,000
Phase I Construction Cost				**$5,450,000**
Engineering & Design				$210,000
Supervision & Inspection				$90,000
Total Phase I				$5,754,000
Phase II (968+80 to 1070+00)				
Mob & Demob	Job	1	Lump Sum	$2,674,000
Dredging				
Offshore Coarse Material				
Sta 1020+00 to 1070+00	CY	261,800	$6.55	$1,715,000
Offshore Mix Material				
Sta 968+80 to 1020+00	CY	678,900	$6.55	$4,447,000
Sub Total - Phase II				$8,836,000
Contingency (15%)				$1,325,000
Phase II Construction Cost				$10,161,000
Engineering & Design				$150,000
Supervision & Inspection				$90,000
Total Phase II				$10,401,000

Item	Unit	Quantity	Unit Cost	Cost
Phase III (785+00 to 900+00)				
Mob & Demob	Job	1	Lump Sum	$3,108,000
Construct Phase III with inlet maintenance material (785+00 to 900+00)	CY	393,800	$7.04	$2,772,000
Nourish Phase I with inlet maintenance material	CY	233,200	$4.75	$1,108,000
Sub Total Phase III & Channel Maintenance				$6,988000
Contingency (15%)				$1,048,000
Phase III Construction Cost & Channel Maintenance				$8,036,000
Engineering & Design				$100,000
Supervision & Inspection				$90,000
Total Phase III & Channel Maintenance				$8,226,000
Phase IV (900+00 to 968+80)				
Mob & Demob	Job	1	Lump Sum	$2,688,000
Construct Sta 900+00 to 968+80	CY	721,500	$5.75	$4,149,000
Nourish Phase II	CY	121,800	$6.55	$798,000
Sub Total - Phase IV & Nourish Phase II				$7,635,000
Contingency (15%)				$1,145,000
Sub Total Phase IV & Nourish Phase II				$8,780,000
Engineering & Design				$75,000
Supervision & Inspection				$90,000
Total Phase IV & Nourish Phase II				$8,945,000
Phase V (581+80 to 785+00)				
Offshore Borrow Area				
Mob & Demob	Job	1	Lump Sum	$1,960,000
Phase V Construction	CY	512,400	$7.31	$3,746,000
Inlet Channel Maintenance				
Additional Mob & Demob	Job	1	Lump Sum	$980,000
Dredging	CY	627,000	$7.04	$4,414,000
Sub Total Phase V & Channel Maintenance				$11,100,000
Contingency (15%)				$1,665,000
Total Phase V Engineering & Design Supervision & Inspection Total Phase V & Channel Maintenance				$12,765,000 $75,000 $90,000 $12,930,000

Channel Maintenance & Periodic Nourishment – Alternative 3

In addition to the two channel maintenance operations that would likely be required during the initial construction phases for Alternative 3, channel maintenance would continue to be required in order to protect the development and infrastructure along the extreme north end of North Topsail Beach. Material removed to maintain the channel would be distributed along the shorelines south of New River Inlet to baseline station 785+00 with the actual disposal locations dictated by observed shoreline and fill behavior. As noted previously, the predicted rate of shoaling in the new channel appears to be sufficient to maintain the beach fill along the entire 37,500 feet of shoreline within the Northern and Central sections of North Topsail Beach. Also, the predicted rate of shoaling would require channel maintenance approximately every four years. Therefore, the annual cost for channel maintenance with disposal of the channel maintenance material along 37,500 feet of shoreline was based on a four year dredging cycle.

In the event material is not available from maintenance of the New River Inlet bar channel, periodic nourishment of the beach fill may have to be augmented with material from the offshore borrow area.

Table 30. Alternative 3 - Costs for maintaining the New River Inlet ocean bar channel every 4 years with disposal on North Topsail Beach to nourish the beach fill project.

Item	Unit	Quantity	Unit Cost	Cost
Mob & Demob	Job	1	Lump Sum	$3,139,000
Dredging	CY	627,000	$7.04	$4,414,000
Sub Total				$7,553,000
Contingencies (15%)				$1,133,000
Sub Total 4-yr Maintenance Cost				$8,666,000
Engineering & Design				$75,000
Supervision & Inspection				$90,000
Total 4-yr Maintenance Cost				**$8,851,000**

Equivalent Average Annual Cost – Alternative 3

The equivalent average annual cost for Alternative 3 was computed using an interest rate of 6% and a 30-year amortization period. The equivalent annual cost presented here assumes all five construction phases and the initial two channel maintenance/beach disposal operations would take place as discussed above followed by channel maintenance/beach disposal every 4 years till the end of the 30-year analysis period. The equivalent average annual cost would be $3,669,000.

Alternative 4 – Beach Nourishment without Inlet Management

Initial Construction – Alternative 4

This alternative involves construction of the interim beach fill plan along the South section (USACE baseline stations 585+00 to 780+00) with the 14 foot dune plan/beach fill design constructed along the Central and North section (USACE baseline stations 785+00 to 1160+00). This alternative does not include any modifications to New River Inlet. Three sources of borrow material were evaluated for Alternative 4; offshore borrow area, upland borrow area, and combination of offshore and upland borrow areas. These three borrow sources are discussed below:

Offshore Borrow Area: Initial construction and periodic nourishment of the beach fill project would be accomplished entirely from the offshore borrow area. The borrow area is located offshore North Topsail Beach between USACE baseline stations 780+00 and 870+00 (approximately 0.4 and 1.6 miles offshore). Based on these analyses, the offshore borrow area was divided into two sections, 1) a 459-acre area with finer grain size (composite mean grain size of 0.21 mm) that contains approximately 6.19 million cubic yards of sand, and 2) a 23-acre area with coarser material (composite mean grain size of 0.33 mm) that contains approximately 356,839 cubic yards of sand for a total of 6.55 million cubic yards. Without the inlet management plan, the total volume of material that would have to be dredged from the offshore borrow area for initial project construction, including the South Section, and periodic nourishment of the Central and North Sections over the 30-year planning period would be in excess of 9 million cy. With only 6.55 million cubic yards available from the identified offshore borrow area; an additional offshore source would be needed to satisfy the project needs.

Given the limited volume of coarse material available from the offshore borrow area, construction of the 14-foot dune plan and beach fill in the areas where nearshore hardbottoms encroach close to shore would be problematic. The coarse grain material from the offshore borrow area would be used to construct the 14-foot Dune Plan between baseline stations 840+00 and 900+00 as well as between baseline stations 1020+00 and 1050+00. This would deplete all of the coarse material in the offshore borrow area resulting in the use of slightly finer material to construct the remaining sections of the 14-foot Dune Plan. The use of the finer grain size material would require approximately 15% more volume to achieve the recommended design beach profile. Since construction of the project using the offshore borrow area will deplete the known source of coarse material, a new source of coarse offshore material would need to be identified in order to avoid possible impacts on the nearshore hardbottom resources. A new offshore source would have to be identified as well to satisfy the 30-year project requirements. The cost of the additional offshore sand search would be approximately $500,000. Assuming the search is successful, the source of the additional coarse grain material will likely be located farther offshore resulting in higher unit dredging costs and higher mobilization and demobilization costs for the periodic nourishment operations.

The cost for implementing Alternative 4 using the offshore borrow area was determined using a phased construction approach as Alternative 3, however; due to the higher costs for using the offshore borrow area for all phases, construction of Alternative 4 would require six (6) phases rather than five. A detailed cost estimate for Alternative 4 using the offshore borrow area is provided in Table 31.

Table 31. Cost Estimates for Phased Construction of Alternative 4.

Item	Unit	Quantity	Unit Cost	Cost
Phase I (1111+00 to 1160+00)				
Mob & Demob	Job	1	Lump Sum	$3,951,000
Sta 1111+00 to 1160+00	CY	720,000	$9.84	$7,085,000
Sub Total				$11,036,000
Contingency (15%)				$1,655,000
Sub Total Phase I				$12,691,000
Engineering & Design				$210,000
Supervision & Inspection				$90,000
Total Phase I				**$12,991,000**
Phase II (1050+00 to 1111+00)				
Mob & Demob	Job	1	Lump Sum	$2,898,000
Sta 1070+00 to 1111+00	CY	597,000	$8.58	$5,122,000
Sta1050+00 to 1070+00	CY	134,200	$8.58	$1,151,000
Sub Total				$9,171000
Contingency (15%)				$1,376,000
Sub Total Phase II				$10,547,000
Engineering & Design				$150,000
Supervision & Inspection				$90,000
Total Phase II				**$10,787,000**
Phase III (972+00+00 to 1050+00)				
Mob & Demob	Job	1	Lump Sum	$2,782,000
Sta 1020+00 to 1050+00	CY	111,700	$7.11	$794,000
Sta 972+00 to 1020+00	CY	644,200	$7.11	$4,580,000
Sub Total				$8,156,000
Contingency (15%)				$1,223,000
Sub Total Phase III				$9,379,000
Engineering & Design				$150,000
Supervision & Inspection				$90,000
Total Phase III				**$9,619,000**
Phase IV (916+00 to 972+00)				
Mob & Demob	Job	1	Lump Sum	$2,633,000
Sta 916+00 to 972+00	CY	750,000	$6.25	$4,688,000
Sub Total				$7,321,000
Contingency (15%)				$1,098,000
Sub Total Phase IV				$8,419,000
Engineering & Design				$150,000
Supervision & Inspection				$90,000
Total Phase IV				**$8,659,000**

Phase V (785+00 to 916+00)				
Mob & Demob	Job	1	Lump Sum	$2,240,000
Sta 900+00 to 916+00	CY	216,300	$4.55	$984,000
Sta 830+00 to 900+00	CY	154,100	$4.55	$701,000
Sta 785+00 to 830+00	CY	461,700	$4.55	$2,101,000
Sub Total				$5,042,000
Contingency (15%)				$756,000
Sub Total Phase V				$5,798,000
Engineering & Design				$150,000
Supervision & Inspection				$90,000
Total Phase V				**$6,038,000**
Phase VI (581+80 to 785+00)				
Mob & Demob	Job	1	Lump Sum	$2,884,000
Sta 581+80 to 785+00	CY	512,400	$7.31	$3,746,000
Sub Total				$6,630,000
Contingency (15%)				$995,000
Sub Total Phase VI				$7,625,000
Engineering & Design				$150,000
Supervision & Inspection				$90,000
Total Phase VI				**$7,865,000**

In addition to the initial construction costs, periodic nourishment would be needed in Phase I in conjunction with the construction of Phase III and in Phases I and II during construction of Phase V. The estimated additional cost for nourishing Phase I during construction of Phase III would be $3,162,000. Periodic nourishment of Phases I and II during construction of Phase V would cost $5,320,000.

Upland Borrow Area: An upland borrow area would be used to construct the beach fill project in the Central and North Section with the South Section constructed using the offshore borrow area.

The Town of North Topsail Beach recently completed a post-Hurricane Ophelia dune restoration project using a combination of truck haul material from Riverside Sand Company, an upland borrow pit located near the Town of Wallace, NC and material scraped from the foreshore profile of the existing beach. An estimated 47,300 cubic yards of borrow material was delivered to the beach at a cost of $1.05 million. Once delivered to the site, additional costs were incurred to transport the material to the dune and shape the material to the design cross-section.

In addition to the Riverside Sand Company, two other potential sources of upland borrow material were identified; Hutcheson Landscaping, Burgaw, NC and Morton Minerals Jackson Pit, Jacksonville, NC. However, only Riverside Sand Company indicated they could satisfy the 9 million cubic yard needs of the project. Therefore, Riverside Sand Company was used to develop cost estimates for the upland borrow area alternative.

The Riverside Sand Company pit is located approximately 65 miles from North Topsail Beach. Assuming truck would travel at an average speed of 50 mph, a roundtrip from the borrow pit to

North Topsail Beach, including load time and dump time would be 166 minutes. For a 12 hour day, one 20 cubic yard trailer dump truck with an effective load of 17 cubic yards could make an average of 4.3 trips per day and deliver 74 cubic yards/day to the beach. During the 16 November to 31 March construction period, one truck could deliver about 9,000 cubic yards to the beach. The quality of material in the sand pit relative to the native beach material is not known at this time; however, the assumption was made that the volume of material needed would be the same as that from the offshore borrow area. The volume of needed to construct the 14-foot Dune Plan in the Central and North Sections totals about 3.8 million cubic yards. Accordingly, the number of truck loads required to construct the project would be around 223,500. If the project was constructed over two construction periods, approximately 210 trailer dump trucks would be needed.

Computation of the unit cost for a cubic yard of truck haul material was based on the daily costs for equipment and personnel and an average daily truck load of 74 cubic yards. The unit cost analysis is given in Table 32.

Table 32. Unit cost estimate for truck haul material.

Item	Daily Cost
Equipment & Personnel:	
Equipment Operator	$400
Oiler	$350
Truck Driver	$310
Hydraulic Excavator	$800
Dump Truck	$500
Total Personnel & Equipment	$2,360
Unit Cost (Based on 74 cy/truck/day)	$32.00/cy
Unit Cost Shaping & Grading:	
Dozer	$1600
Dozer Operator	$400
Sub Total Shaping & Grading ($/day)	$2,000
Unit Cost Shaping & Grading (900 cy/day)	$2.20/cy
Cost of Sand at Borrow Pit ($/cy)	$4.00/cy
Total Unit Cost Truck Haul Material	**$38.20/cy**

The total cost to construct the North and Central Sections of the project using an upland borrow source and the South Section using the offshore borrow area is shown in Table 32a and totals over $156 million. This initial construction cost far exceeds the cost for Alternative 3 and is beyond the financial capability of the Town of North Topsail Beach.

Table 32a. Cost estimate for Alternative 4 using upland borrow area for North and Central Sections and the offshore borrow area for the South Section.

Item	Unit	Quantity	Unit Cost	Cost
Phase I				
Truck Haul				
Sta 972+00 to 1160+00	CY	2,207,081	$38.20	$3,600,000
Sub Total Phase I				$84.310,000
Engineering & Design				$150,000
Supervision & Inspection				$90,000
Total Phase I				$88,150,000
Phase II				
South Section (Offshore)				
Mob & Demob	Job	1	Lump Sum	$2,884,000
Dredging (581+80 to 785+00)	CY	512,400	$7.31	$3,746,000
Sub Total				$6,630,000
Contingency (15%)				$995,000
Sub Total Phase II				$7,625,000
Engineering & Design				$150,000
Supervision & Inspection				$90,000
Total South Section				**$7,865,000**
Truck Haul				
Sta 785+00 to 972+00	CY	1,582,100	$38.20	$60,437.000
Total Phase II				$68,302,000
Total Alternative 4 (Combined Offshore & Truck Haul)				**$156,452,000**

Combination Upland Borrow Area and Offshore Borrow Area: Due to the sensitive nature of the near shore hard bottom areas, the known source of coarse material in the offshore borrow area would be used to construct the project from baseline stations 840+00 to 900+00 and baseline stations 1020+00 to 1050+00. The offshore borrow area would also be used to construct the interim fill in the South Section. The remainder of the project would be constructed using material from the upland borrow source identified above. The total initial construction cost for Alternative 4 using a combination of truck haul and offshore borrow material is detailed in Table 32b and would be over $150 million. Again, this initial construction cost is much greater than Alternative 3 and beyond the financial capability of the town of North Topsail Beach.

Table 32b. Cost estimate for Alternative 4 using a combination of offshore and upland borrow areas.

Item	Unit	Quantity	Unit Cost	Cost

Phase I – Offshore Borrow Area				
Mob & Demob Offshore Borrow Area	Job	1	Lump Sum	$2,884,000
Dredging Cost				
Sta 830+00 to 900+00 (Coarse)	CY	154,100	$4.55	$701,000
Sta 1020+00 to 1050+00 (Coarse)	CY	111,700	$7.11	$794,000
South Section	CY	512,400	$7.31	$3,746,000
Subtotal				$8,125,000
Contingency (15%)				$1,219,000
Sub Total Phase I				$9,344,000
Engineering & Design				$150,000
Supervision & Inspection				$90,000
Total Phase I (Offshore Borrow Area)				$9,584,000
Phase II – Truck Haul				
Sta 785+00 to 830+00	CY	461,700	$38.20	$17,637,000
Sta 900+00 to 972+00	CY	966,300	$38.20	$36,913,000
Sta 972+00 to 1020+00	CY	644,200	$38.20	$24,608,000
Sta 1050+00 to 1070+00	CY	134,208	$38.20	$5,127,000
Sta 1070+00 to 1160+00	CY	1,316,973	$38.20	$50,308,000
Total Phase II - Truck Haul				$134,593,000
Total Alternative 4 – Upland & Offshore				**$150,263,000**

Periodic Nourishment – Alternative 4

Over the course of the 30 year project period, a total of 9,002,781 cubic yards of material would be needed to maintain the 14-foot Dune Plan in the Central and North Sections. For Alternative 4, all periodic nourishment material would have to be obtained from offshore borrow sources or upland borrow pits. Upland borrow sites do not appear to be an economical or practical option due to the high unit cost and the number of trucks that would be required to deliver the material to the beach as discussed above. Initial construction of Alternative 4 would deplete all presently known sources of coarse grain material in the offshore borrow area, accordingly, additional offshore sand searches would be needed to locate a sufficient quantity of coarse grain material to nourish the sections of the project which have hardbottoms located close to shore, otherwise, the nearshore hardbottom resources could be negatively impacted. The cost of the additional offshore sand search would be approximately $500,000. Assuming the search is successful, the source of the additional coarse grain material will likely be located farther offshore resulting in higher unit dredging costs and higher mobilization and demobilization costs. Periodic nourishment costs for Alternative 4 are given in Table 33.

Table 33. Alternative 4, 4-year periodic nourishment costs with material from an unknown offshore borrow source.

Item	Unit	Quantity	Unit Cost	Cost

Mob & Demob	Job	1	LS	$2,898,000
Sta 780+00 to 830+00	CY	88,300	$8.60	$759,000
Sta 830+00 to 900+00	CY	123,700	$8.60	$1,064,000
Sta 900+00 to 1020+00	CY	212,100	$8.60	$1,824,000
Sta 1020+00 to 1160+00	CY	247,500	$8.60	$2,129,000
Sub Total				$8,674,000
Contingency (20%)				$1,735,000
Sub Total Nourishment				$10,409000
Engineering & Design				$150,000
Supervision & Inspection				$90,000
Total Nourishment				**$10,649,000**

Equivalent Average Annual Cost – Alternative 4

The equivalent average annual cost for Alternative 4 was computed for the offshore borrow area option using an interest rate of 6% and a 30-year amortization period. The search for additional offshore coarse sand sources was assumed to occur following Phase II with the cost of this sand search equal to $500,000. The equivalent average annual cost of Alternative 4 would be $4,964,000.

Alternative 5 – Beach Nourishment with One-Time Channel Relocation

Initial Construction and Periodic Nourishment

The initial construction costs for Phases I and II would be the same as Alternative 3. With the inlet channel only being relocated once, construction of Phase III would occur with material from the offshore borrow area. The estimated total cost for Phase III would be $5,149,000. Periodic nourishment of the Phase I shoreline would also be needed at the same time Phase III is constructed. The additional cost to nourishment Phases I during construction of Phase III would be $3,162,000. Construction of Phase IV would cost $7,883,000 with Phase V construction costs equal to $7,790,000. The shoreline from New River Inlet to station 785+00 would need to be nourished during construction of Phase V with the cost of nourishment using offshore borrow sources equal to $10.6 million.

Equivalent Average Annual Cost – Alternative 5

The equivalent average annual cost for Alternative 5 was computed using an interest rate of 6% and a 30-year amortization period. The search for additional offshore coarse sand was also assumed to occur immediately following completion of initial construction. The equivalent average annual cost of Alternative 5 would be $4,120,000.

Alternative 6 – Inlet Management Only

Initial Construction and Periodic Nourishment – Alternative 6

Material from the initial construction of the New River Inlet bar channel would be equally distributed along the shorelines of the Central and North Sections while construction of the South Section would be accomplished using the offshore borrow area. Periodic nourishment for the Central and North Sections would come from maintenance of the New River Inlet bar channel. A summary of the initial and periodic nourishment costs for Alternative 6 is given in Table 34.

Table 34. Cost estimate for Alternative 6, inlet management only.

Item	Unit	Quantity	Unit Cost	Cost
Phase I – Inlet				
Mob & Demob	Job	1	LS	$3,139,000
Dredging Cost				
Beach Fill	CY	544,400	$7.04	$3,833,000
Upland Disposal	CY	91,400	$4.21	$385,000
Additional mob & demob + dike and outfall structure	Job	1	LS	$400,000
Sub Total Inlet				$7,757,000
Contingency (15%)				$1,164,000
Sub Total - Phase I				$8,921,000
Engineering & Design				$75,000
Supervision & Inspection				$90,000
Total Phase I				**$9,086,000**
Phase II - South Section				
Mob & Demob	Job	1	LS	$2,884,000
Dredging Cost	CY	512,400	$7.31	$3,746,000
Sub Total Construction Costs				$6,630,000
Contingency (15%)				$995,000
Total Construction cost - Phase II				$7,625,000
Engineering & Design				$75,000
Supervision & Inspection				$90,000
Total Phase II				**$7,790,000**
Periodic Nourishment				
Mob & Demob - Inlet	Job	1	LS	$3,139,000
Dredging Cost	CY	584,000	$7.04	$4,414,000
Sub Total				$7,553,000
Contingency (15%)				$1,133,000
Sub Total Nourishment				$8,686,000
Engineering & Design				$75,000
Supervision & Inspection				$90,000
Total Nourishment				**$8,851,000**

Equivalent Average Annual Cost – Alternative 6

The equivalent average annual cost for Alternative 6 was computed using an interest rate of 6% and a 30-year amortization period. The equivalent average annual cost of Alternative 6 would be $3,134,000.

Comparison Average Annual Costs and Average Annual Damages Prevented

A comparison of the net benefits associated with Alternatives 3 to 6 is provided in Table 35. Net benefits, given in Table 35 are the differences between equivalent average annual damages prevented and the equivalent average annual costs for each alternative. Note that the equivalent average annual costs include the annualized costs for constructing the interim protection project in the South Section; however, damage reductions associated with the South Section are not included in the comparison. Annual damages prevented for each alterative were presented in the previous section and represent the difference in annual damages with the plan versus average annual damages for the No Action Alternative.

Table 35. Comparison of equivalent average annual costs and average annual damages prevented for Alternatives 3, 4, 5, and 6.

Alternative	Equivalent Annual Damages Prevented	Equivalent Average Annual Costs	Net Equivalent Annual Benefits
3	$25,040,000	$3,669,000	$21,371,000
4	$18,100,000	$4,964,000	$13,136,000
5	$18,970,000	$4,120,000	$14,850,000
6	-$10,320,000	$3,134,000	-$13,454,000

Summary – Comparison Costs and Damage Reductions

The maximum difference between annual costs and the annual reduction in damages is produced by Alternative 3, which includes construction of the 14-foot Dune Plan in the Central and North Sections, implementation of the inlet management plan for New River Inlet, and construction of an interim protection project for the South Section. Alternative 6, which primarily involves the inlet management plan, would potentially increase the storm damage potential in the Central and North Sections since most oceanfront structures and structures located immediately south of New River Inlet were assumed to remain in place during the 30-year evaluation period. Alternatives 4 and 5 would provide reasonable levels of damage reduction; however, the equivalent annual costs for these two alternatives exceed the equivalent annual cost of Alternative 3.

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APPENDIX C

Geotechnical Investigations